# ESSAYS ON HOUSING AND MONETARY POLICY

**Min-Ho Nam**

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**January 2013**

I, Min-Ho Nam, hereby certify that this thesis, which is approximately 69,000 words in length, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for a higher degree.

Date: January 15, 2013. Signature of candidate:____________________

I was admitted as a research student in September 2009 and as a candidate for the degree of Doctor of Philosophy in September 2009; the higher study for which this is a record was carried out in the University of St Andrews between 2009 and 2012.

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I hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of Doctor of Philosophy in the University of St Andrews and that the candidate is qualified to submit this thesis in application for that degree.

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*To the people distressed by the sub-prime crisis,*

*especially to those whose houses were foreclosed by bankers*

*partly because of the failures of monetary policy and monetary economics*

# Preface

In the midst of the housing boom period in the last decade, there were heated debates inside and outside the central banking community whether the then level of house prices overshot the level consistent with economic fundamentals and whether central banks should intervene by raising policy rates. The orthodox answers from the Federal Reserve to such questions exercised the predominant influence on the opinions of other central banks: it is extremely hard to identify 'bubbles' and interest rates are a blunt instrument which may not have expected effects. Again, the conventional *mop-up at once* strategy beat alternative strategies. However, I chose to be among the sceptics asking myself the following questions: whether there is really no criterion for detecting housing bubbles, how economic agents form expectations about future house prices, what factors affect their expectations, whether low interest rates bolstered the housing boom in the last decade and, if so, how that can be substantiated, and whether the attempts of central banks to curb the development of a housing bubble are always ineffective and sub-optimal. This scepticism ignited my academic voyage thereafter.

The initial task of this voyage was to acquire a good command of technical tools useful for answering these questions and to have a firm understanding of past research findings on the dynamics of house prices. Though challenging, the process was quite enjoyable and it was additionally delightful to read such classics as Wicksell, Cassel, Keynes, Schumpeter, Fisher, Minsky, etc. As my understanding of the relationship between the housing market and monetary policy deepened, more questions were added to the initial set: what role the developments and deregulations in housing finance as well as the overall financial sector played in generating the volatile trajectory of housing prices, whether there are any transmission channels of monetary policy affecting housing prices which central banks may not have noted when forecasting the developments of the housing market and their repercussions on the overall economy.

Such questions have acted as a lighthouse during the voyage. However, some of the queries have not been tackled in sufficient depth in my study. For example, I was initially optimistic that heterogeniety of expectations can be modeled to explain house price fluctuations, but this still remains merely an idea. Nevertheless, my voyage has been rewarding in several ways. I have had time to establish my views not only on the issues raised in the first phase of my voyage but also on broader topics such as; what macroeconomists should do to contribute to preventing economic catastrophes, in which direction modern capitalism should evolve, and what the societal obligations of central bankers should be in the context of recent economic crisis for which they are also partly responsible for laying the foundations alongside other government agencies and banks.

As in the case of other people, my research voyage was demanding and underwent plenty of stormy weather and harsh waves. Among certain things I came to realize during the journey is that I could not have arrived at this humble port without the support of other people. Most of my academic achievements are owed to the dedicated help from my supervisor, Professor Kaushik Mitra. The discourses with him helped pinpoint drawbacks in the logics presented in each chapter and showed me how to improve them. In addition, he has vast experience of the psychological up-and-downs of researchers and hence was able to give useful advice on how to proceed without stranding a ship at a strange beach. I also appreciate his considerations of not only my academic but also personal circumstances during the past three years. Dr. Taesu Kang has spurred me to deepen my understanding of macro-modeling and answered my questions in developing DSGE models in this thesis. He has been with me unceasingly from the very beginning and is a lifetime benefactor of mine. Dr. Paolo Gelain currently working at the Norges Bank introduced me to New-Keynesian models and has given me valuable directions to best lead the life of a Ph.D candidate when he stayed as a research fellow at St Andrews. Dr. Seong-Hoon Kim, who attended the same university for undergraduate study as me and came to St Andrews as a member of the teaching staff, has stimulated my research in various dimensions and shared the agonies about my research. Dr. Ozge Senay encouraged me to proceed with warm consolations when I felt depressed by my failure to make progress. Regarding the third chapter of this thesis, I should pay a special tribute to Dr. John V. Duca, the vice president of the Federal Reserve Bank of Dallas, for having provided the loan-to-value ratio data estimated by him and his co-authors. In addition, he sent warm solaces and stimuli for my study once in a while. Orachat Nyomsuk, who spent several years together with me as another Ph.D candidate in our school, also encouraged me to make progress. Dr. Ruth King at the School of Math & Statistics allowed me to audit the module of *Bayesian Inference* she taught. Other staff members of the School of Economics & Finance were very helpful in terms of both my research and living in general. The kind support of Angela and Caroline, the administrative staff at the school office, is much appreciated. The smiles by some students who heartily expressed their gratitude for the tutorials I taught in the Candlemas Semester of 2010 were the most invigorating for me since my mood then was the lowest.

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Looking far back, there are more benefactors who helped me embark on this voyage. My superiors at the Bank of Korea, Director Hee-Sik Jung and Ju-Hyun Kim, and Senior Economist In-Sun Hwang imbued me with a fundamental motivation to study economics to a higher level. Director Myung-Jong Lee encouraged me to finish my ph.d study. I should also express enormous gratitude to my friends who sent warm support from outside the U.K.; Gil-Won Kang, Gi-Cheon Son, Ho-Gil Choi, Soo-Young Kim and other friends and my colleagues at the Bank of Korea. Anthony Scott, my British friend currently living in Korea, gave precious comments on some expressions in this thesis. The mental support from my lifetime guru, Mr. Byoung-Cheol Oh, is greatly appreciated.

I appreciate the financial support from the Bank of Korea and the generous scholarship from Scottish Institute for Research in Economics (SIRE). Their financial assistance was pivotal to my being able to continue my research in the U.K.

I express special gratitude to Professor Kap-Young Jeong, President of Yonsei University, and Professor Seunghwan Suh of the same university and Professor Young-Han Kim at Sungkyunkwan University who wrote recommendation letters as my referees when I applied for a place to do Ph.D study.

Lastly, the support of my family was essential and indispensable in surmounting the hardships I have experienced. My wife, Seon-Jeong Kim, and my children, So-Mi and Ho-Beom, have been with me even on rainy days shedding beautiful sunlight on my soul. She, in particular, had to endure an extreme isolation and solitary life in St Andrews suppressing her homesickness. I cannot express in words how much I feel indebted, sorry and thankful to her. I also feel so grateful to my sisters and brothers for their concern about our lives.

My mother, Ms. Young-Ja Park, who continued sending warm consolations and was waiting patiently for my family and I to return to Korea contributed the most to this thesis.

Min-Ho Nam
October 2012

# Abstract

This thesis, motivated by my reflections about the failings of monetary policy implementation as a cause of the sub-prime crisis, attempts to answer the following inquiries: (i) whether interest rates have played a major role in generating the house price fluctuations in the U.S., (ii) what are the effects of accommodative monetary policy on the economy given banks' excessive risk-taking, and (iii) whether an optimal monetary policy rule can be found for curbing credit-driven economic volatilities in the model economy with unconventional transmission channels operating.

By using a decomposition technique and regression analysis, it can be shown that short-term interest rates exert the most potent influence on the evolution of the volatile components of housing prices. One possible explanation for this is that low policy rates for a prolonged period tend to encourage bankers to take on more risk in lending. This transmission channel, labelled as the *risk-taking channel*, accounts for the gap to some extent between the forecast and the actual impact of monetary policy on the housing market and the overall economy. A looser monetary policy stance can also shift the preference of economic agents toward housing as theoretically and empirically corroborated in the context of choice between durable and nondurable goods. This transmission route is termed the *preference channel*. If these two channels are operative in the economy, policy makers need to react aggressively to rapid credit growth in order to stabilize the paths of housing prices and output.

These findings provide meaningful implications for monetary policy implementation. First of all, central bankers should strive to identify in a timely fashion newly emerging and state-dependent transmission channels of monetary policy, and accurately assess the impact of policy decisions transmitted through these channels. Secondly, the intervention of central banks in the credit or housing market by adjusting policy rates can be optimal, relative to inaction, in circumstances where banks' risk-taking and the preference for housing are overly exuberant.



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*Keywords*: Housing cycle; Monetary policy; Interest rates; Expectation; Risk-taking channel; LTV ratio; Borrowing constraint; Housing preference; Risk-taking channel; Credit-driven volatilities

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# Introduction

The global financial crisis crippled the functioning of the financial system and brought about unprecedented damages to the real economy. These huge negative repercussions caused by the vicious housing cycle of some advanced and developing economies devastated the everyday lives of the common people. For example, according to Financial Crisis Inquiry Commission (FCIC, 2011) published by the U.S. government, homes of about four million families have been foreclosed and another four and a half million are subject to the foreclosure process. More astounding is the growth rate of household debt. According to the report, the increase in U.S. household debt over the six year period from 2001-07 matched the level of indebtedness over the entire history of the country prior to 2001. During the recession following the housing market crash, the rate of unemployment soared to 10% in October 2009 from the pre-crisis level of about 4% and still hovers around 8% as of 2012. According to the U.S. Labor Department reports, about 7 million people lost their jobs between 2007 and 2009 and the number has increased even further since then.

Evidently and admittedly, there is no sole reason for the calamity. With the benefit of hindsight, financial deregulation, inadequate financial supervision, deflation-averse monetary policy for a prolonged period, bounded rationality of economic agents and global saving glut are recognized as the main reasons for the sub-prime crisis. For example, FCIC (2011) concludes that the following factors fed the housing boom and triggered the crisis: widespread failures in financial regulation and supervision, failures of risk management at financial institutions, a combination of excessive borrowing and risky investments, inconsistent policy stance of the government, a systemic breakdown in accountability and ethics, and deteriorating mortgage-lending standards. Stiglitz (2009) points out as the causes of the 'free fall' of the U.S. economy; low interest rates, excessive risk-taking by banks, lax regulation and securitization worsening the problems of imperfect information. Obstfeld (2010) considers monetary policy to be the single most important factor for the occurrence of the crisis; the low interest rate environment brought about housing price inflation, exuberance in mortgage lending, substantial home equity withdrawal and excessive leverage by financial market participants. Duca *et al* (2010) provides a superb review of the existing views while giving more emphasis to the role of innovations in housing finance, expectations about house prices and the combined effect of all the main factors. Rajan (2010), while agreeing with the consensus view, recognizes the inequality problems which exacerbated since the 1970s as the deep-seated cause of the crisis. He regards credit expansion and poor regulation as the secondary causes. Diamond and Rajan (2009) stress large bank holdings of mortgage-backed securities alongside the usual reasons.

In contrast to the aforementioned reasonings, some emphasize the effects of the huge influx of foreign capital from emerging markets. Reinhart and Rogoff (2009) designate as fundamental reasons a huge inflow of foreign capital and more accommodative regulatory policy. Greenspan (2010) asserts that subdued long-term interest rates maintained by the persistent and large demand for U.S. Treasury Bills initiated and fed the housing bubble and that the ultimate driver of the crisis was the innately greedy nature of humankind. He adds that short-term interest rates which can be manipulated by the Fed were not responsible for triggering the housing boom.

In spite of these findings, research is still ongoing into what was the root reason was and how the housing prices in the U.S. could reach such an unsustainable level. Just after the crisis erupted, it was maintained that the extra loose policy stance of the Federal Reserve over an extended period had driven housing prices to the unsustainable level and hence it should take responsibility for the subsequent burst of the housing market bubble and the ripple effects on the overall economy.[1] Although the assertion was refuted by staff at the Fed[2], numerous empirical findings reveal that low interest rates propelled the housing market into the overheated phase, induced overheated investments in housing and caused excessive credit expansion feeding the housing bubble.[3] Unfortunately, the debate terminated inconclusively because any decisive evidence was not provided. Still, as history has taught us, we need to do our utmost to illuminate further the role played by monetary policy in the crisis formation process and derive lessons for monetary policy implementation to evade similar kinds of economic disasters in the future. In light of that, efforts to answer the following questions will shed some light on future policy decisions. Are interest rates the main driver of housing boom-bust cycles and, if so, how do they change housing prices? Why did policy makers fail to forecast the full impacts of the housing cycle on the overall economy? Was the failure due to a misunderstanding of monetary policy transmission channels? If another exuberant episode in the housing market or other asset markets occur, how should central banks react?

There already exist some answers to these questions. Regarding the question of whether interest rates are important in driving housing prices, Bjørnland and Jacobsen (2010) find that house prices are fairly sensitive to monetary policy shocks and Iossifov *et al* (2008) concludes that interest rates are a prime determinant of house prices. In terms of transmission channels of monetary policy, Borio and Zhu (2008) and Rajan (2006) point out the missing channels through which low interest rates abet the risk-taking by economic agents. Recent empirical findings, representatively Jiménez *et al* (2008), support that hypothesis. Regarding the final question proposed above regarding whether central banks should react to abnormal expansion of credit or rapid rise of house prices, Pariés and Notarpietro (2008) and Kannan *et al* (2009) provide evidence that central banks should intervene in the housing and credit markets by adjusting policy rates.

[1] Taylor (2007) holds this viewpoint.

[2] Dokko *et al* (2009) and Bernanke (2010) insist that monetary policy decisions during the first half of the last decade were appropriate even from the perspective of the Taylor rule and there is no evidence for the causal link between such decisions and the housing boom.

[3] Other arguments have been proposed as well. Kahn (2009) attributes the housing boom in the U.S. to resurgence in productivity. Wheaton and Nechayev (2008) assign importance to population and income growth in addition to interest rates.

This thesis is another attempt to answer these questions. Starting from a review of the long-debated issues regarding the implications of housing price inflation for monetary policy, it explores the role of interest rates in generating cyclical movements in housing prices. Next, it introduces the previously neglected transmission channels of monetary policy, namely the *risk-taking channel* and *preference channel*, and finally concludes that central banks should react to growth of asset prices or credit to enhance macroeconomic stability in case these channels are operative.

Specifically, the first chapter summarizes the previous discussions on the issues surrounding the identification of bubbles, accountability of monetary policy for housing bubbles and the necessity for central banks to intervene in the housing market. In the prevalent viewpoint, the identification of or judgement as to the existence of a bubble has been considered the most daunting task and feasible only after a bubble bursts. The main findings from the empirical research published before the housing market crash in the U.S. are introduced and a critical review of these findings is added. Thereafter theoretical reasoning about how monetary policy decisions influence housing prices and the related empirical evidence are provided. The last part of the chapter compares the competing stances of the Fed and ECB in terms of whether central banks should take action against a persistent rise in housing prices.

The second chapter examines the validity of the assumption underlying the debate on whether monetary policy decisions were responsible for the recent boom-bust episode of the U.S. housing market. Irrespective of conflicts between the two stances, it was implicitly assumed that interest rates were the main driver of the bubble in house prices. However the empirical literature provides inconclusive evidence for the dominant role of interest rates in house price dynamism. Based on a comprehensive review of existing literature combined with my own work, a hypothesis is proposed that not only just interest rates but also expectation play major roles in rendering house prices more volatile. To examine its validity, a different regression strategy from the one commonly adopted is employed. In the common type of regression model, the dependent variable is a measure of cyclical component rather than the level of the house price itself extracted from a series on house prices by a filtering technique. The empirical results obtained using the U.S. data support the hypothesis proposed above; namely they confirm the primacy of interest rates in generating house price fluctuations and the importance of the expectation channel in transmitting the effects of interest rates.

The third chapter aims to analyze the transmission effects of accommodative monetary policy on the overall economy through the *risk-taking channel* operating in the mortgage market within a DSGE (Dynamic Stochastic General Equilibrium) framework. To achieve this, the analysis involves two steps. Firstly, the relationship between short-term rates and LTV (loan-to-value) ratio is estimated using U.S. data from 1980 to 2007 to verify the existence of the *risk-taking channel*. Secondly, the estimated relationship is incorporated in a general equilibrium model featuring borrowing constraints and the housing market to construct the virtual economy in which the *risk-taking channel* takes effect. The results from the first-stage empirical analysis confirm that the channel has operated in the U.S. mortgage market; the LTV ratio has an upward trend if the federal funds rate decreases. The ensuing DSGE analysis reveals that if the *risk-taking channel* comes into force, a positive monetary policy shock to the economy generates further deviations of consumption and debt from the steady state than otherwise. Moreover, if lenders adjust the LTV ratio after taking into account their expectations of policy rates and housing prices, the channel exerts a stronger influence on the economy. These results suggest that under a low interest rate environment, monetary policy analysis needs to take the *risk-taking channel* into account. In addition, regulatory reactions to excessive risk-taking behaviours in the banking sector can be an appropriate measure for smoothing the path of real and financial activities.

The fourth chapter aims to illustrate that an expansionary monetary policy shock renders the economy more volatile once transmission impacts through the preference for housing and bank's risk-taking are considered in addition to through the traditional transmission channels. To achieve this aim, I modify a workhorse DSGE model by incorporating the impact of policy rates on housing preference and LTV ratio based on empirical evidence.

Since an easier monetary policy stance likely increases the LTV ratio by lowering the risk perception of bankers and consequently expanding the demand for housing, credit grows rapidly and the economy becomes more volatile as in the run-up to the sub-prime crisis. An optimal reaction of monetary policy to this *credit-driven* economy from the perspective of macroeconomic stability is also examined in this chapter. Comparing the performances of various alternative policy rules, the rule requiring an aggressive response to credit fluctuations ensures a better performance than a standard Taylor rule when faced with an exuberant predilection for housing and excessive risk-taking by banks.

# Chapter 1

# Issues on the Relationship between Housing and Monetary policy

In this chapter, the theoretical issues on the relationship between housing and monetary policy and the related empirical findings are summarized with a critical review. The issues are (i) whether a certain observed level of housing price can be defined as a 'bubble' or not, (ii) whether monetary policy decisions are accountable for bubbles, (iii) whether monetary policy should respond to house price appreciation, and lastly (iv) to what extent and through what channels house price fluctuations influence real economic activities. These questions are closely interconnected and particularly important from a policy point of view. For example, if the current level of housing prices proves to be sustainable and on a path of equilibrium consistent with economic fundamentals such as income growth, consideration of the remaining questions becomes largely irrelevant.

The practical implications for monetary policy can be clarified by taking the Federal Reserve (Fed) as an example during the boom phase of the housing market. Considering the stance expressed in the articles by the Fed staff and speeches by the members of Federal Reserve Board of Governors, the then likely answers to the questions in 2006 can be inferred as follows:

(i) it is hard to conclude a bubble exists in the housing market even though the housing prices are rising rapidly, (ii) it is uncertain that a housing market boom can be accounted for by the accommodative stance of the Fed, (iii) monetary policy decisions are ineffective for curbing the speed of house price inflation and the artificial bursting of the bubble before its peak costs substantially more compared with waiting for a natural collapse, and (iv) housing affects overall economic growth and employment via consumption and residential investment.[1] These answers lead to a scenario for taking policy actions as follows: if the prospective housing downturn is more likely to induce an economic recession, policy interest rates need to be kept low to attain full employment and price stability. This scenario was realized as we all observed.

The remainder of this chapter is structured as follows. In section 1.1, issues on the definition of and identification of a bubble are summarized, and the related empirical findings are introduced. In section 1.2, it will be discussed whether monetary policy is responsible for bubbles. Section 1.3 tackles a practical issue of whether central banks should react to bubbles and compares the stances of the Fed and ECB in respect of that issue. In the last section, the empirical findings about the influences of changes in house prices on consumption and investment activity are provided.

## 1.1 Does a Bubble Exist?

### 1.1.1 Definition of Bubble

The question whether there exists a bubble in housing prices arises repeatedly whenever the price level in real terms is approaching or surpassing its previous peak. For that reason, the debate on the existence of a bubble was reignited during the period of the boom phase, namely 2004-2007, in the U.S. The starting point in the debate, as in the previous ones, was to derive a definition of a bubble as there was no firmly established one. The most frequently cited definition by researchers in that field comes from Stiglitz (1990):

[1] These answers are inferred from the stance expressed in Kohn (2006).

> If the reason that the price is high today is only because investors believe that the selling price will be high tomorrow-when *fundamental* factors do not seem to justify such a price-then a bubble exists. (pp.13)

Case and Shiller (2003) underscore the part of "*investors believe*" in that definition rather than "*fundamental factors*":

> The notion of a bubble is really defined in terms of people's thinking: their expectations about future price increases, their theories about the risk of falling prices, and their worries about being priced out of the housing market in the future if they do not buy. (pp. 301)

Their definition misses the connection between expectation and other economic factors. In reality, it may be rare that investors' expectations depend solely on pure belief or passively accept what other investors perceive. Rather, a bubble is generated and magnified by support from economic fundamentals and credit supply. Several objective conditions, such as ample liquidity or low borrowing cost, should be met for a bubble to emerge as noted by Kindleberger (1978).

In my opinion, it seems more appropriate to use the term 'bubble' to refer to the *extent* to which house prices deviate from an equilibrium level justifiable by underlying economic activities. In other words, the term seems to be related to *degree* rather than *substance*. In light of these points, I define a bubble as follows.

> A bubble refers to the *phenomenon* in which asset prices exceed a certain critical level which can be justified by fundamental determinants of the demand for and supply of housing.

Besides, a bubble can be defined as below from a retrospective viewpoint:

> A certain level of asset prices can be regarded as a bubble if the asset prices turned downward quickly responding sensitively to a minute change in one of the objective conditions which had previously supported that level.

### 1.1.2 Measuring a Bubble and Judging its Existence

As can be perceived with ease, the definitions above hardly provide any practical guidance on how to judge whether the observed level of house prices are overvalued because no quantitative criterion is included there. This is the very reason why most of the past debates on a bubble's existence before its burst terminated inconclusively. However, even though there has been no agreement on what measure should be used to confirm the presence of a bubble, two ratios are still being prevalently employed: house price-to-income ratio and rent-to-price ratio. Price-to-income ratio reflects investors' average affordability of housing. Rent-to-price ratio is the measure for judging whether the current price level is in line with the fundamental value of housing on the premise that rents represent the changes in the determinants of housing prices just as dividends from equity are viewed as a proxy for the intrinsic future value of a company. A different reasoning can be derived from the rent-to-price ratio. If the current level of house prices were overvalued, market participants would choose to rent a house instead of buying. As a result, the demand for housing for the purpose of owning decreases and house prices decline.

During the first several years of this century, economists outside central banking and academic circles mainly resorted to these two indices to maintain that the U.S. housing market was already in a bubble state and the trend in the housing market would reverse in the near future. For example, Baker (2002) regards the rise in housing prices in the U.S. since 1995 as a bubble based on the fact that the gap between the subindex of rent in the CPI (Consumer Price Index) and the housing price index widened and historically such a discrepancy has been reduced by subsequent falls in housing prices. Hatzius (2006) speculates that house prices in 2005 were overvalued by 15% according to the price-to-income ratio.

However, McCarthy and Peach (2004) and Himmelberg *et al* (2005) raise doubts about these assertions. The former starts from the criticism that the conventional measures fail to reflect the effects of low mortgage interest rates. This obscures the significant implications for affordability and for the equilibrium return on housing which equals rent-to-price ratio. If the decline in mortgage interest rates are appropriately reflected in calculating the ratios, it turns out that the maximum amount of loans increased almost 130% from 1990 to 2003 and the price of a standard single-family home can be regarded as reasonable from a cash flow standpoint. Turning to rent-to-price ratio, they criticize the conventional way of computing the ratio based on the fact that the subindex of rent in the CPI, the numerator in the ratio, controls for quality change whereas the home price index compiled by OFHEO, the denominator, disregards it.[2]

To overcome such shortcomings, they modify the conventional computation process in two ways. Firstly, the OFHEO house price index is replaced by the constant-quality new home price index compiled by the U.S. Bureau of the Census.[3] Secondly, by subtracting interest rates and property tax rate from the rent-to-price ratio computed by the first way, an adjusted ratio is calculated.[4] The two types of rent-to-price ratio show a relatively more stable path compared to the ratio estimated in the conventional way. These findings lead them to conclude that house price increases are driven chiefly by low mortgage interest rates and growth in income, and thus there is no evidence of house price overvaluation.

Himmelberg *et al* (2005) share the spirit of McCarthy and Peach (2004) in that they employ the user cost of capital as a conceptual instrument for judging whether housing is mispriced and criticize the conventional computation for not taking the time series pattern of real long-term interest rates into account. The *imputed rent to actual rent ratio* and *imputed rent to income ratio* devised by them are used to judge whether the level of these indices as of the end of 2004 are at or near the previous peak. They maintain that the concept of the user

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[2] The OFHEO refers to the Office of Federal Housing Enterprise Oversight which was merged into the Federal Housing Finance Agency (FHFA) based on the law "Housing and Economic Recovery Act of 2008" on July 30, 2008.

[3] It is dubious whether identical quality adjustment method is used in compiling the constant-quality rent in CPI and house price index.

[4] Based on the reasoning of Poterba (1984) and the formula of user cost defined by Jorgenson (1963), the arbitrage condition between renting and purchasing of a house is specified as below.

$$R_t = P_t[(1 - \tau_t^y)(i_t + \tau_t^p) + \delta_t - E(\pi_t^H)]$$

where $R_t$ denotes the implicit rent of the structure, $P_t$ is the home price index, $\tau_t^y$ is the income tax rate, $\tau_t^p$ is the property tax rate, $\delta_t$ is the depreciation rate, and $E(\pi_t^H)$ is expected capital gains from the housing asset. MaCarthy and Peach (2004) modifies this formula for calculating the adjusted rent-to-price ratio as below.

$$(R_t/P_t) - [(1 - \tau_t^y)(i_t + \tau_t^p) + \delta_t] = E(\pi_t^H)$$

cost, the annual cost of home ownership termed the *imputed rent*, has an advantage over the common rent-to-price ratio approach in that the concept of user cost is closer to the economic cost of renting a house. The formula of the user cost, $u_t$, defined in terms of the cost per dollar for owning a house, is given as

$$u_t = r_t^{rf} + \omega_t - \tau_t(r_t^m + \omega_t) + \delta_t - g_{t+1} + \gamma_t \tag{1.1}$$

where $r_t^{rf}$ and $r_t^m$ denote risk-free interest rate equivalent to the opportunity cost of buying a house and mortgage interest rates respectively. $\omega_t$ is property tax rate and $\tau_t$ is income tax rate. The multiplicative term $\tau_t(r_t^m + \omega_t)$ means the mortgage interest and property taxes deducted from income tax. $\delta_t$ refers to maintenance costs, $g_{t+1}$ is expected capital gains in the next period and $\gamma_t$ is the risk premium accrued to homeowners. According to their speculation, fluctuations in user costs, caused by, for instance, changes in interest rates or taxes, lead to predictable changes in the rent-to-price ratio which reflect not bubbles but fundamentals.

Based on the finding that the *imputed rent to actual rent ratio* as well as *imputed rent to income ratio* measured at the end of 2004 are not as high as the levels of previous peaks, they argue that mispricing in the housing market cannot be verified. An additional finding follows that the two ratios are more volatile and distinct in the era of historically high or low interest rates than other periods. It concludes that this finding suggests the observed housing boom was being propelled by economic fundamentals.

Case and Shiller (2003) also contradict the evident existence of a bubble by implementing a different approach. They employ not only the conventional measures but also the results of a survey which investigates the motives for home buying and expectations about the future path of house prices. Its main finding is that home price appreciation is driven by economic fundamentals such as income growth and low interest rates, which is consistent with the conclusions of McCarthy and Peach (2004) and Himmelberg *et al* (2005). However, they also emphasise the survey result which indicates that speculative components in home prices were observed in several metropolitan cities.

### 1.1.3 Comments

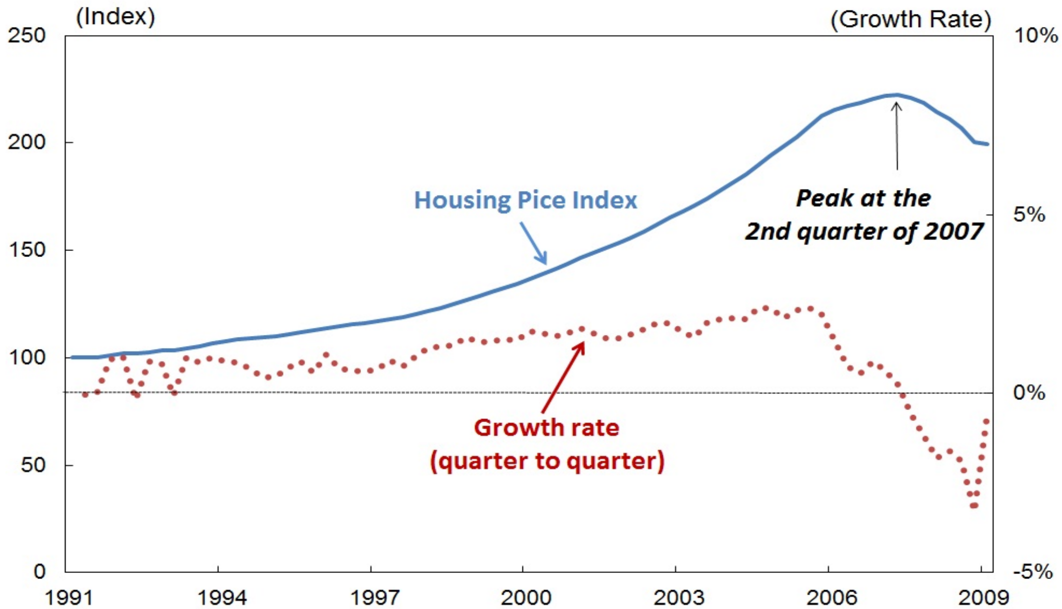
Firstly, it is worth questioning whether the judgments in the literature above prove to be consistent with the subsequent evolution of the housing market thereafter. As can be seen in Figure 2.1, housing prices increased persistently until the second half of 2007 and decreased afterwards. With hindsight, there seems to be no denying that evidently there existed a bubble as even Greenspan (2010) acknowledges (although he did not indicate so during his tenure at the Fed). However, the ex-post discerning of the bubble does not contradict the findings of the literature introduced above in that the researchers utilized the time series of house price index before 2003 or 2004. Furthermore, as I defined earlier, the term *bubble* should refer to *degree* rather than *substance*. In light of that, it remains unclear whether or not the judgements in the literature were creditworthy at the time. However, it appears that the researchers underestimated the strength of the momentum driving the upward phase of the housing market.

Secondly, apart from the estimation and quality adjustment issues in calculating price-to-income and rent-to-price ratios, the shortcoming in defining a bubble in Himmelberg *et al* (2005) needs to be discussed. They define a housing bubble as below:

> We think of a housing bubble as being driven by home buyers who are willing to pay inflated prices for houses today because they expected unrealistically high housing appreciation in the future. (pp. 1)

This definition, alongside Case and Shiller (2003), highlights only expectational aspects in the motive of investors to purchase housing while ignoring that expectations evolve depending on the developments in objective economic conditions such as overall financial state, monetary policy and economic growth. Their definitions are based on the assumption that market participants are irrational and unrealistic, expressed as *irrational exuberance* or *excessive*

**Figure 1.1. Housing Prices in U.S. after 1990s**




Note: The index is seasonally-adjusted purchase-only index.
Source: Federal Housing Finance Agency (FHFA)

*optimism*, in a certain period and the objective conditions bear no relationship with these expectations.

In my view, the role that monetary policy played in the process of expectation formation is disregarded in the literature. The continued low interest rates appear to have not only increased the affordability of housing but also have reinforced the expectations of further house price appreciation. The causal link running from interest rates and liquidity to housing prices, which will be elaborated on in the following section, was possibly perceived to a certain extent by the market participants. Furthermore, the 'benign' neglect of the boom in the housing market by the Fed may have motivated the public to expect that at least house prices would not depreciate rapidly. It is because investors conjectured that a swift fall in housing prices would certainly be detrimental to the overall economy and hence the central bank would take rescue measures, including lowering of interest rates, to boost the overall economy.

Lastly, the failure in the forecasting of future house prices in Case and Shiller (2003) exemplifies the shortcomings of excessive dependence on the psychological aspects of investors. They foretold as of 2003 that the house price level would decline in the near future based on their findings that investors' confidence about future appreciation of real estate prices was not as strong as in the late 1980s. The forecast proved to be wrong as house prices began to decline only after the second half of 2007 as Figure 2.1 shows.

## 1.2 Is Monetary Policy Accountable for Bubbles?

Voluminous literature reports empirical findings about the relationship between monetary policy (or its main instrument) and housing price inflation. Since these research findings will be presented in great detail in the subsequent chapters, here I will provide only three selected perspectives about how monetary policy accounts in part for bubble formation.

### 1.2.1 Theoretical Basis for Role of Monetary Policy in Housing Bubbles

The following three perspectives are widely recognized in the literature of how monetary policy induces housing price inflation: the *user cost* perspective, the *liquidity* perspective and the *expectation* perspective. All of these perspectives are related to the changes on the demand side.[5]

First, the user cost perspective has provided the most potent and convenient tool for explaining changes in house prices since the early 1980s. If policy makers decide to lower policy rates, the decision diminishes the opportunity cost of buying a house and provides the possibility of capital gain if housing prices respond normally to the change in interest rates. Consulting the formula of the user cost can help understand this reasoning more clearly. To

[5] Chapter 2 provides various perspectives about how housing prices are determined in terms of both supply and demand in the housing market. Based on the assumption that supply of housing is fairly inelastic, we confine our interest to here the demand side.

rewrite the formula[6] specified above,

$$u_t = r_t^{rf} + \omega_t - \tau_t(r_t^m + \omega_t) + \delta_t - g_{t+1} + \gamma_t \tag{1.2}$$

If the central bank lowers policy rates, the risk-free interest rate $r_t^{rf}$ which influences the opportunity cost of owning a house will fall. As ownership becomes more attractive than previously, the demand for housing increases. Moreover, if potential home buyers expect that housing prices are more likely to rise in that low interest rate environment, the future capital gains $g_{t+1}$ will increase.

Second, different from the user cost perspective, the liquidity perspective puts more weight on the indirect channel of interest rates via *liquidity effect* under the assumption that a more accommodative monetary policy leads to ampler liquidity through the traditional monetary policy transmission mechanism. Meltzer (1995) represents the typical logic of monetarists about the influence of monetary shock on real asset prices. An expansionary monetary policy shock lessens the relative level of marginal utility of *money* against *other assets* by increasing the stock of money. To restore equilibrium by enhancing the marginal utility of money, economic agents spend the surplus money in buying financial and real assets, which results in asset price inflation. He takes the housing market collapse in Japan in the early 1990s as an example for this asset market model. The growth rate of money in the late 1990s accelerated as the Bank of Japan absorbed the U.S. dollars earned by exports to the U.S. to maintain the fixed exchange rate agreed between the two governments. Sterilization necessarily entailed expansion of domestic liquidity. In turn, the speedy increase of money raised the level of expected inflation and as a consequence raised the demand for housing.

Third, the expectation perspective, explored initially by Case and Shiller in the research on housing, mainly pertains to the derivative effects of house price appreciation on psychological motivation to purchase housing. Notably, this is related to the lack of action on the part of the

[6] Explanation for the notations in the equation were presented on pp. 12.

central bank rather than any action on its part. As noted previously, Himmelberg *et al* (2005) mention that neglecting a bubble by a central bank (rather than trying to burst it) can build the expectations that house prices will not fall in the short-term. This inaction may incite risk-taking by home buyers and expand the demand for housing. On the other hand, observing house prices inflate continuously imbues anxiety into potential first-time home-buyers that they may be priced out of the market. This anxiety also contributes to strengthening the motive to buy homes in the short-term.

### 1.2.2 Review of Empirical Findings

It is worth mentioning several summary points of the empirical research to be introduced below. Firstly, among empirical studies, Detken and Smets (2004) and Adalid and Detken (2007) seek the theoretical foundation for their findings from Meltzer (1995). In other words they adopt the liquidity perspective of monetarists. Secondly, most studies employ VAR techniques while Detken and Smets (2004) use a filtering method and Iacoviello and Neri (2010) employ a DSGE framework. Thirdly, all studies except for Negro and Otrok (2007) validate the hypothesis that the environment of lower interest rates is one of the drivers of the housing boom.

To begin with, Detken and Smets (2004) elicit stylized facts about the economic developments associated with past asset price booms in 18 OECD (Organization of Economic Cooperation and Development) countries. Although the aggregate real asset price index constructed in the paper includes not only real residential estate prices but also real commercial estate prices and real equity prices, the stylized facts derived can be true of housing and the methodology for discovering the facts provides a useful guidance for future study.[7]

The first step in the methodology is estimating the trend of the index by employing a one-sided Hodrick-Prescott Filter and then calculating the asset price gap which is defined as the

[7] The weights used to compute aggregate prices are the relative share of each of the three assets in the wealth of the private sector. The weight given to real asset prices is far higher compared with to other two.

discrepancy between the actual level of the index and the extracted trend. The second step is to identify the boom periods; this is defined as a period in which the aggregate real asset price index exceeds the trend by more than 10%. The final step is to calculate the medians of asset prices and a variety of economic variables and then look for differences in the medians of the variables in the three artificially segmented periods which are pre-boom, during-boom and post-boom periods.[8] The pre-boom and post-boom periods are defined as two years before and after the identified boom period.[9]

Three stylized facts are notable. First, growth rate is higher immediately before and during the boom period. Second, policy rates are lower than the Taylor rule prescriptions by 2 percentage points in the during-boom periods. Third, the growth rates of real credit and real money are robust before and during the boom. Additionally, the growth rates of credit and money decelerate more appreciably after a considerable slowdown in economic activity following the *high-cost booms* which by definition are the booms followed by a fall of over 3 percentage points in average real growth. This suggests that *high-cost booms* may be correlated with looser monetary conditions. These facts can be true of the housing sector since the aggregate asset price index constructed moves in tandem with real residential estate prices. A caveat follows that these findings merely about an association between monetary policy and asset price booms, and have nothing to say about a causal connection.

Adalid and Detken (2007), based on the findings of Detken and Smets (2004), explicitly aim to estimate the causal relationship between liquidity and real estate prices by eliminating the endogeneity problem which arises as the growth of liquidity interacts with asset price fluctuations. To attain this aim, a VAR approach is employed using the sample statistics from 18 OECD countries from 1970 to 2004. Although the effectiveness of the VAR approach in eliminating the endogeneity problem is uncertain, the results obtained by a panel VAR

[8] The variables include real and monetary variables. The real variables are Gross Domestic Product (GDP), consumption and investment. The monetary variables are credit growth, money gap and the Taylor gap.

[9] The paper also applies the same procedure to *high-cost booms* (which by definition are booms followed by a fall of over 3 percentage points in average real growth) to examine the distinguishing features of economic development during high-cost booms.

analysis reveal that real residential estate prices appreciate slightly over 1% subsequently if money grows by 1% on average in the previous six quarters.

Goodhart and Hofmann (2008) pay more heed to the interplay among money variables, house prices and real economic variables based on theoretical considerations. However, the theoretical basis is not firmly verified and includes the more or less ambiguous relationship between economic variables. The main argument is that house prices, credit and consumption via the wealth and collateral effects and residential investment are closely interrelated. The paper, in particular, especially highlights the interaction between credit and house prices whereas the previous literature emphasized only a one-directional link running from liquidity to housing prices. Apart from testing this interaction, they examine an additional hypothesis that monetary shocks have more impact on house prices during the boom periods in the OECD countries.

It might be informative to review shortly the empirical model in understanding these findings.

$$Y_{i,t} = A_t + A(L)Y_{i,t} + \varepsilon_{i,t} \tag{1.3}$$

where $Y_{i,t}$ is a vector of endogenous variables, $A_t$ is a matrix of country-specific fixed effect, $A(L)$ is a matrix of polynomial in the lag operator.[10] Through Granger causality tests, they find that monetary variables and house prices exerta significant mutual influence, on the one hand, and on future GDP growth on the other hand. However, in terms of future CPI, only money growth turns out to be important. A separate analysis with a VAR model augmented with a dummy variable shows that monetary shocks are more influential on house prices in the boom period.

The following three empirical studies focus on the U.S. housing boom. Jarocinski and Smets

[10] The vector of endogenous variables consists of 6 differenced variables, real GDP ($\Delta y$), consumer price index ($\Delta cpi$), short-term nominal interest rate ($\Delta ir$), the nominal residential house prices ($\Delta hp$) nominal broad money ($\Delta m$), nominal private credit ($\Delta c$). All the variables are in log difference form except for the nominal interest rate.
$Y = [\Delta y, \Delta cpi, \Delta ir, \Delta hp, \Delta m, \Delta c]'$

(2008) use a Bayesian VAR (BVAR) model to assess the role of housing and monetary policy in the U.S. business cycle from 1987 Q1 to 2007 Q2. The following 9-variable BVAR models of order five are specified both in levels and in growth rates. The vector of endogenous variables in the level-VAR (L-VAR) and the differences-VAR (D-VAR) are given respectively as below:

$$\begin{aligned} \text{L-VAR} &: [y,\, c,\, p,\, HI/Y,\, hp - p,\, cp,\, i,\, s,\, m] \\ \text{D-VAR} &: [\Delta Y,\, \Delta c,\, \Delta p,\, HI/Y,\, \Delta hp - \Delta p,\, \Delta cp,\, i,\, s,\, \Delta m] \end{aligned} \tag{1.4}$$

where $i$ denotes the federal funds rate, $s$ is the long-term interest rate spread, $HI$ is the residential investment and $Y$ is nominal GDP. $y$ is real GDP, $c$ is real consumption, $p$ is the GDP deflator, $hp$ is nominal house prices, $cp$ is commodity prices and $m$ is money stock. $\Delta$ in the D-VAR is a lag operator. The authors assign more credibility to the results of D-VAR than L-VAR. One of their important findings is that a substantial fraction of housing price inflation during 2004 to 2005 can be accounted for by the low level of short and long-term interest rates, but not by GDP developments. However, the developments in GDP are proven to explain the continued growth of house prices after the economic slowdown in 2001 and 2002.

Iacoviello and Neri (2010) develop a DSGE model which features common New Keynesian assumptions such as sticky nominal prices and wages, borrowing constraints and heterogeneity among the two production sectors for housing and non-housing goods. Furthermore, housing is assumed to directly affect the utility functions of households and can be provided as collateral for bank loans. The model is estimated using quarterly U.S. data over the period 1965 Q1 to 2006 Q4. The main aim of the model estimation is in gauging the extent to which the housing market has contributed to business fluctuations in the U.S. However, the relationship between monetary policy and house prices is derived from the structural nature of the model and this makes it possible to recognize the structural factors that have driven house prices in the past. One of the main estimation result is that looser monetary conditions maintained by the Fed explains a considerable part of the house price inflation from 2000 to 2005. In addition, the low level of short and long-term interest rates are found to have bolstered the housing boom during from 2004 to 2005.

Lastly, Negro and Otrok (2007) delve into the magnitude of response of house prices to the monetary policy shocks during the (housing) boom period after 2000. To resolve the well-known problem that the aggregate housing price index blurs the unique properties of housing markets in each state, a dynamic factor model is employed and the aggregate housing price index is decomposed into three hierarchical levels which are national, regional and state level. It finds that the impact of the monetary policy shock alone is not negligible, but the magnitude of its influence is trivial compared to the influence of the high growth rate of house prices. However, it is questionable whether the maintained assumption is plausible; that house prices can be decomposed into three distinct dimensions and monetary policy influences only the national factor. This assumption might result in underestimating the effects of monetary policy since local factors presumably are influenced by changes in policy rates.

To synthesize the empirical findings mentioned above (setting aside model uncertainty and robustness issues), loose monetary policy conditions and strong credit growth are likely to have been a main cause of the housing market booms, at least for the most recent boom in the U.S. The limitation of these studies is that the theoretical exposition of the causality running from monetary policy to housing prices is not adequate and it is difficult to derive implications for monetary policy implementation in the future.

## 1.3 Should the Central Bank Respond to House Price Appreciation?

Arguments for the normative role of the central bank in periods of asset price appreciation appears repeatedly in the history. The most recent examples are the arguments for aggressive intervention by the central bank during the U.S. high-tech boom in the late 1990s and the housing market booms in several industrialized countries from 2000 to 2007. In this section, we discuss various arguments about whether central banks should intervene in the midst of bubble expansion. Depending on the arguments for the necessity of central banks to raise interest rates in reaction to bubbles, the stances can be classified into three categories: these stances of the Fed, the ECB and *leaning against the wind* strategy.

### 1.3.1 Stance of the Fed: *Conventional Strategy*

The Fed has never enunciated its stance about whether it should react to asset price bubbles. If any, governors at the Fed have expressed their opinions in speeches with the familiar caveat that their own opinion should not be misunderstood as the official stance of the Fed or a consensus among their colleagues. However, one can derive a consistent position from these speeches.[11]

The conclusions implicit in these speeches can be summarized as follows: the best strategy in tackling asset price bubbles is to wait until a bubble bursts by itself and then minimize its adverse aftereffects on the overall economy by lowering the federal funds rate. This stance is expressed relatively clearly in Greenspan (1999).

> Such straying above fundamentals could create problems for our economy when the inevitable adjustment occurs. It is the job for economic policymakers to mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion.

There are several arguments for this implicit stance. The first is the difficulty in discerning bubbles. The argument goes that a bubble is inherently unidentifiable in a timely fashion because uncertainty is substantial surrounding the measures and models for judging the presence of a bubble.

The second argument against *extra action* is based on scepticism about the effectiveness of

[11] The relevant speeches are Greenspan (2002), Bernanke (2002), Ferguson (2005), Kohn (2006, 2007, 2008), Mishkin (2008) and the related article is Mishkin (2007).

monetary policy in decelerating the appreciation speed of targeted asset prices.[12] The scepticism arises from the following three considerations. First, monetary policy is an ineffective instrument for aiming at a specific type of asset class in that changes in policy rates influence not only other asset prices but also real economic activities. In that context, monetary policy is viewed as a tool mainly for achieving maximum employment under stable inflation. Second, it is hard to estimate the scale of speculative component latent in the observed price level of an asset. Furthermore, the impact of monetary policy on the speculative elements have been barely understood. The Fed believes that a moderate measure such as a 1 or 2% rate hike has proven to be ineffective in curbing the evolution of bubble. It is because expected capital gains during boom periods usually exceed the increase in opportunity cost caused by the rate hike to a considerable extent. These effects are compounded by the lags involved in policy affecting asset prices. There seems to be a belief shared among the Fed staff that the width of policy rate hike enough to suppress exuberant atmosphere in asset markets is likely to bring about substantially subdued economic activities.

The third argument for not adopting the *extra action* strategy is the view that the potential benefits of checking speculation in asset markets do not suffice to justify the central bank's intervention. Raising interest rates inevitably induces the side-effect of slower economic growth and volatile expectations about future inflation. Furthermore, the Fed insists that such side-effect should be smaller than that of reduced economic activities brought about by the self-correction in asset markets. As Bernanke (2001) shows by means of a simulations, the benefit in terms of reduced output-gap of responding to stock prices is overwhelmed by the increased variability of inflation. However, Kohn (2008) concedes that considering the magnitude of negative repercussions caused by the collapse of the housing market in the U.S., the gain of *extra action* in this episode might have been larger than expected before the sub-prime crisis fully unfolded.

[12] The term *extra action* was coined by Kohn (2006) which refers to a tighter policy stance to confront the inflation in asset prices while the *conventional strategy* means the policy where the central bank responds to asset price developments only when they have crucial implications for future output and inflation. The former action is referred to *proactive* and the latter as *reactive* monetary policy by Bordo and Jeanne (2002). Trichet (2005) labels the former the *orthodox view*.

### 1.3.2 Leaning Against the Wind

The strategy of *leaning against the wind* refers to a circumspect response to raise policy rates in reaction to asset price bubbles while accommodating a deviation of inflation from the targeted level of price stability. The preconditions for the implementation of the strategy are that the existence of a bubble is perceived and its harmful implications for the overall economy are evident. The greatest benefit of the principle is recognized as the prevention of possible moral hazard which can be fostered under the *conventional strategy*. As stated previously, if economic agents expect the implementation of a simple reactive strategy by the central bank, the bubble can inflate more due to a higher level of risk-taking compared with the case of *leaning against the wind*. Hence, taking *extra action* can reduce disruptive repercussions following the bursting of a bubble. Despite the potential benefits, *leaning against the wind* is recommended under the following strict conditions. First, the probability of the bubble bursting should be low. Second, asset prices should react swiftly to changes in interest rates and finally the overall efficiency loss in the economy should be proportional to the magnitude of the bubble. An additional condition is that the misalignment of asset prices with fundamentals should be the result of underlying structural imbalances which can be corrected by prudential regulations.

### 1.3.3 Stance of the ECB

Whereas the Fed has never announced its official stance about whether to intervene in asset markets while adhering to the tacit *conventional strategy*, the ECB explicitly and formally admits that it can resort to *leaning against the wind* strategy in special circumstances.[13] Trichet (2005) represents the position of the ECB in a lucid way.

> As discussed a moment ago, allowing some short-term deviation from price stability in order to better ensure price stability over more extended horizons might (under very restrictive assumptions) be the optimal policy to follow. The principle behind it should

[13] Related references are Issing (2003), ECB (2005), Trichet (2005) and Papademos (2006). Issing (2003) differentiates the cautious intervention of the ECB from *leaning-against-the wind* because he regards the latter as equivalent to *popping bubbles*.

> not be misunderstood as a systematic reaction to asset price booms, but rather as a selective response based on the careful analysis of all the available information.

As recognized widely, the primary objective of the ECB is to maintain price stability which is defined as *below and close to 2%* with a medium-term orientation. This medium-term horizon, the ECB asserts, allows it to tolerate short-term disparity between the actual and the desired level of inflation on the premise that asset price misalignments have significant implications for price stability over the medium-term. The prime argument for implementing this *cautious approach* is that monetary policy intervention during asset price booms can prevent the problem of moral hazard by maintaining symmetry in policy response.

It would be interesting to investigate where the difference in the stances of the Fed and ECB originate from. Even though it requires a separate study, possible sources for the different views may include: (i) the disparate stipulation about their objectives,[14] (ii) the relative weight placed on the role of monetary analysis, (iii) the ECB's confidence about the strong correlation between money and asset prices and (iv) the different time horizons of policy implementation.

## 1.4 Effects of Changes in House Prices on Real Economy

Evaluating the magnitude of the effect of house price changes on economic sectors is essential for forecasting the future path of the economy after house price deflation and choosing proper policy measures to support its resilience. For example, Leamer (2007) demonstrates that the eight recessions in the U.S. economy happened mainly because of the significant slowdown in residential investments. The channels through which changes in house prices influence consumption and investment can be summarized as three: wealth channel, collateral channel

[14] *Article 105* in The Treaty stipulates that the objective of the ECB is to *maintain price stability and without prejudice to the objective of price stability, the ESCB (European System of Central Banks) shall support the general economic policies in the Community* whereas Section 2a in the Federal Reserve Act specifies the goals of monetary policy as to *maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates.*

and Tobin's Q channel. The first channel affects household consumption whereas the second influences all types of entrepreneurial investment as well as consumer spending. The last channel is mainly about residential investment.

### 1.4.1 Wealth Effect

The wealth effect is widely recognised since the life-cycle hypothesis states that increases in wealth affect consumption positively irrespective of the type of wealth. Households try to smooth their consumption path by spending unexpected gains on their wealth as owners of houses show tendency to consume more in the presence of house price appreciation. Even though several issues regarding the wealth effect remain controversial, empirical findings mostly assign a positive sign to this effect.[15] The size of that effect differs depending on empirical findings. Mishkin (2007) states that the long-run marginal propensity to consume out of wealth in the U.S. is estimated as 3.75% in the Fed model. Jarocinski and Smets (2008) estimate the impulse response of real consumption to be 7.5% after four quarters in response to a 1% permanent increase in real house prices. Iacoviello and Neri (2010) find that the estimated house price elasticity of consumption is 7%; a figure similar to that in Jarocinski and Smets (2008).

### 1.4.2 Collateral Effect

The collateral effect has gained prominence gradually since the financial liberalisation of the 1980s and more rapidly in the past decade. Bernanke *et al* (1999) provide a theory on the important linkage between the value of collateral and demand for bank lending. Here the information asymmetry problem produces cost to lenders as they try to verify the true economic state and future cash flow of borrowers. The cost acts as an additional premium to the risk-free interest rate. As a result, the value of collateral is negatively associated with

[15] The first issue is whether the effects differ depending on the type of wealth. A second issue is whether the increase in housing wealth may dampen consumption as future home buyers increase savings. Mishkin (2007) provides detailed explanations.

the *finance premium.* If the value of collateral rises, it reduces the possible loss in the event of default on loans as well as the information cost incurred by monitoring whether borrowers undertake riskier projects. In turn, increases in the value of collateral lead to decreases in the finance premium. Thus, the improved balance sheet caused by rises in house prices induces lenders to be willing to supply credit at lower interest rates. That can stimulate further borrowing by households as well as firms facing credit constraints. Subsequently, credit expansion fuels consumption and entrepreneurial investment.

On the other hand, increases in home value also directly raise the maximum borrowing amount even if the loan-to-value ratio remains constant since collateral value also affects the ceiling on borrowing. As we observed during the housing boom period, the so-called mortgage equity withdrawal (MEW) increased appreciably as house prices rose. Evidently, the quantitative effect of housing price appreciation on the amount of credit available expands consumption positively especially in the case of financially constrained households. In addition to the effect on consumption, the collateral effect can be applicable to entrepreneurial investment as well because firms finance bank funding by providing collateral such as lands and machinery.

Related research has became livelier after the credit extended to the private sector grew rapidly as a result of house price inflation in the run-up to the financial crisis. I take Iacoviello and Neri (2010) as a representative case for the purpose of brevity. In their model, households are classified as patient and impatient ones. While patient households lend funds to firms and impatient households, impatient households provide the minimum level of wealth required for a down payment on their home and are facing a collateral constraint in their borrowing. This constraint is expressed as:

$$b_t \leq m\ E_t(q_{t+1} h_t \pi_{t+1} / R_t) \tag{1.5}$$

where $b_t$ refers to borrowing, $m$ is loan-to-value ratio, $q_{t+1}$ is the real price of housing, $h_t$ is the stock of housing, $\pi_{t+1}$ is the overall level of inflation and $R_t$ is nominal interest rates.

This constraint states that the amount of borrowed money should not exceed a fraction $m$, the LTV ratio, of the expected house price in the next period. They confirm the impact of the collateral constraint on consumption imposed in their model because the coefficient of housing wealth in a reduced-form regression of consumption differs widely depending on the level of $m$. A basic regression in their model is given as below.

$$\Delta \log C_t = 0.004 + 0.123\ \Delta \log HW_{t-1} \tag{1.6}$$

where $C_t$ is consumption and $HW_{t-1}$ is housing wealth in the previous period. The estimated coefficient of housing wealth decreases to 0.099 in the absence of collateral effects, namely $m = 1$, whereas it rises to 0.150 when $m$ is set to 0.5. They conclude that their model is in line with the theoretical reasoning that the higher is the proportion of households who use their home as collateral, the stronger is the wealth effect on consumption.

### 1.4.3 Tobin's Q Effect

One of the stylized facts found by Detken and Smets (2004) is that the growth rate of real GDP is close to a 3.5% per annum when the housing boom is in progress and immediately before the boom begins. On the other hand, it drops to 1.3% after the boom ends. To a considerable extent, the variations are due to fluctuations in residential investment. Intuitively, the simple dynamics of supply and demand can explain the effects of changes in housing prices on residential investment. As the level and growth rate of house prices increase, the user cost of home ownership decreases owing to positive capital gains. In turn, the demand for housing expands and, responding to that, the supply side reacts to exploit more profitable opportunities.

The hypothesis above can be supported by theoretical considerations from Cummins *et al* (2006) and Topel and Rosen (1988). Cummins *et al* (2006) postulate that investment is a positive function of the shadow price of capital. In the model, a firm maximizing the expected present discounted value of future profits considers the relationship between investment and the shadow price of capital. It is formulated as follows.

$$\frac{I_t}{K_{t-1}} = \delta + \frac{1}{\alpha}(q_t - 1) + \omega_t \tag{1.7}$$

where $I_t$ denotes investment, $K_{t-1}$ is capital stock in the previous period, $\delta$ is the rate of depreciation, $\alpha$ is a constant, $q_t$ is the shadow price of capital and $\omega_t$ is the productivity shock.[16] As they expound, in the Neoclassical framework marginal $q$ becomes identical to Tobin's Q under the specific conditions of linear homogeneity in net revenue function and perfect competition. If the Neoclassical proposition is combined with the conditional equivalence of $q$ to Tobin's average Q, this implires that construction companies would expand new investment should the equity price of the company rise on expectations about future profit increases.

Topel and Rosen (1988) present the relationship directly by associating housing value with investment. A simplified form of the related equation is given as below.

$$\varphi I(t) = \theta P(t) - \tau C(t) \tag{1.8}$$

where $I_t$ is investment, $P_t$ is the price of one unit of housing, $C_t$ is the cost function, and all coefficients of $\varphi$, $\theta$ and $\tau$ are assumed to be positive and close to zero.[17] Hence the investment is positively affected by the price of housing.

It is still inconclusive empirically whether a rise in Tobin's Q enhances new investment in reality. Cummins *et al* (2006) finds that the elasticity of investment-capital ratio to a unit

[16] The derivation of this equation is based on profit maximization together with a standard adjustment cost technology. The derivation is presented on pp.6-7 of Cummins *et al* (2006).

[17] The original equation is given by

$$(1 + r\beta D - \beta D^2)I(t) = \left(\frac{\beta}{C_{22}}\right) P(t) - \left(\frac{\beta}{C_{22}}\right) [C_1 + rC_2 + C_{13}y(t)] \tag{1.9}$$

where the terms $C_i$ and $C_{ij}$ are derivatives of cost function with respect to $I_t$, $D$ is the first derivative with respect to time, $r$ is interest rate and $\beta = C_{22}/(C_{11} + rC_{21})$. The derivation process can be found on pp.722-723.

increase in Tobin's Q is over unity in a panel data analysis of 4 years of sample data of companies recorded in a database.[18] Topel and Rosen (1988), based on the equation linking house prices to investment, elicit a supply function of housing by regressing single-family house prices and other variables on new housing starts over the period 1963 Q1 to 1983 Q4. The basic regression function is given as follows.

$$I_t = \beta_0 + \beta_2 P_t + \beta_3 y_t + \nu_t \tag{1.10}$$

where $I_t$ is new housing starts during the period $t$, $P_t$ is the quality adjusted real house price index and $y_t$ is the vector of variables shifting costs. The price elasticity of new housing investment implied by the estimate of $\beta_2$ is 2.76 in the long run if the price change is permanent.[19] Turning to sensitivity to temporary changes in housing prices, the elasticity of investment to a 1% change of housing price lasting for two years is 1.68 in the current period with the same model specification.

In Iacoviello and Neri (2010), the baseline estimate of the house price elasticity of residential investment is slightly over 3.5% in the first year in a reduced form regression. This is higher than the estimate of Topel and Rosen (1988).

## 1.5 Concluding Remarks

The main issues regarding the relationship between the housing sector and monetary policy has been reviewed; accountability of monetary policy for housing booms, an appropriate strategy of central banks in reacting to the excessive inflation of house price and the spill-over effects of the housing sector to the entire economy.

The first issue will be probed in greater detail through a review of the past studies on

[18] The finding is also true for *real Q* constructed by the authors using the expected earnings of analysts instead of real earnings records.

[19] The authors view this as the best estimate among their estimation results which differ widely depending on the model specifications.

the determinants of house price. Chapter 2 will provide an additional answer through a regression analysis to that question whether monetary policy has been a main driver of house price fluctuations. This analysis is based on an empirical testing for the significance of the impact of interest rates on housing cycles. The second issue will be tackled in Chapter 4 to examine the relative efficiency of different policy rules if they are implemented in the model economy similar to the pre-crisis circumstances in the last decade. Finally, the influence of the housing sector on the whole economy will be analyzed by adopting a DSGE framework in both Chapter 3 and 4.

# Chapter 2

# Housing Cycle and Interest Rates

## 2.1 Introduction

The main topics in the research on housing have changed to help solve the circumstantial issues arising from a specific situation as in other research fields. In the 1970s, the era of high inflation, researchers focused on the influence of inflation on housing prices and households' affordability of housing. Later, as the baby boom generation in the U.S. exited from the household formation cohort in the late 1980s, the influence of changes in demographics emerged as the main issue in forecasting the future evolution of the housing market. From the beginning of this century, various issues have been raised with regard to the observed exuberant behaviour of all types of participants including households, banks and investors in the housing markets of the U.S. and several European countries. During the same period, researchers came to recognize more clearly that the role of the housing sector in terms of business cycle and monetary policy conduct became increasingly important. The list of the debated issues include the existence of a bubble, the accountability of monetary policy decisions for the housing boom and the effectiveness of monetary policy intervention to curb housing price inflation. While researchers' interests in the first and last issue have waned to some extent, the second issue is still receiving intense attention as the debate continues on whether the sub-prime crisis can be attributed to the accommodative policy stance adopted during the first half of the past decade.[1]

In that debate, the side arguing for the responsibility of the extra loose monetary policy for the crisis, represented by Taylor (2007), cites as the evidence that the actual level of policy interest rates for the same period remained below the Taylor rule prescriptions in the U.S. Adding to that, Jarocinski and Smets (2008) and Iacoviello and Neri (2010) also find through a VAR and DSGE approach, respectively, that the low level of policy rates affected house price appreciation considerably at least during the period from 2004 to 2005.[2] The stance represented by Taylor, designated as the *conventional wisdom* by Greenspan (2010), entailed a deluge of retorts from both inside and outside the central bank community. The main issues raised in that discussion are firstly, the degree of accommodativeness in monetary policy, secondly, the magnitude of the influence of the federal funds rates (FFR) as short-term interest rates on housing demand, and lastly, the applicability of Taylor's contention to other countries which experienced a similar degree of house price appreciation as the U.S.

As regards the first issue, Dokko *et al* (2009) and Bernanke (2010) contend that the policy decisions of the Fed during 2002-2006 were not so loose as initially perceived by observers adhering to the *conventional wisdom.* This judgement is based on the finding that the Taylor gaps estimated in Taylor (2007) by far exceed the gaps estimated by using an inflation index[3] different from common CPI (Consumer Price Index) and unrevised data for output and inflation in the Taylor rule formula.

For the second issue, Greenspan (2010) maintains that long-term interest rates were the main driver of the housing boom since a considerable proportion of mortgages in the U.S. is linked to 30-year fixed interest rates. Since long-term rates, he argues, were subdued for

[1] The discussion on this topic appeared from at the beginning of this century as in BIS(2003, Ch 6. Financial Markets), Tsatsaronis and Zhu (2004) *inter alia.*

[2] However, Dokko *et al* (2009) interprets the results as monetary policy accounting for only a small fraction of house price increases in the same period. From my viewpoint, their interpretation appears to underestimate the influential power of monetary policy in the results.

[3] The index is the core PCE (Personal Consumption Expenditure) price index.

**Figure 2.1. House Price and Interest Rates in U.S.**


Data Source: Federal Reserve, Standard and Poor's Case & Shiller Index
Note: The shaded area represents to the period from the 3rd quarter of 2004 to the 2nd quarter of 2006.

a prolonged period (presumably due to the global saving glut), he seems to conclude that the tremendous stockpiles of savings in the Asian emerging markets were the root cause of the housing boom. He also points out the limitation of implementing the Taylor rule in investigating the issue since no input in the equation is related to housing demand and hence a lower level of policy rate than the level calculated by the rule is not necessarily followed by house price inflation.

The last issue, i.e., the generality of the *conventional wisdom*, is examined by Kannan *et al* (2009). They find that there is only negligible association in 21 advanced countries between the accommodative degree of monetary policy identified by the negative Taylor residuals and house price appreciation.

An additional ground for denying the *conventional wisdom* in Dokko *et al* (2009) and Kohn (2008) is that monetary policy stance was tight during the most exuberant period of the housing market from the third quarter of 2004 to the second quarter of 2006. However, even though house prices peaked during that period, the growth rate continued decreasing during the same period as can be observed in Figure 2.1. This fact reflects the gradually weakening momentum of housing prices during that period and hence such period cannot be referred to as 'the most exuberant one'. Furthermore, considering the delayed response of house prices to the changes in macroeconomic variables, their assertion hardly provides any implication for solving that issue.

Despite the stark contrast in the two competing stances, they shared two assumptions. Firstly, interest rates are the primary determinant of housing demand and secondly, the increase in demand drove the housing boom. The participants in the debate take it for granted that the demand for housing responds most sensitively to interest rates, be it short-term or long-term, nominal or real, and variable or fixed. Even Greenspan (2010), who has ascribed the crisis to an extraordinarily low level of risk aversion, admits that "the global house price bubble was a consequence of lower interest rates." However several questions naturally arise. Does there exist evidence of the prime role of interest rates in house price determination? Can we disregard the possibility that other usual house price determinants, such as income, might affect house prices more than interest rates?

As regards the first question, there is conflicting evidence regarding the role interest rates play in determining housing demand. Even with a cursory look at the existing empirical results summarized in Girouard *et al* (2006) and Iossifov *et al* (2008), wide variation in the magnitude of the coefficient of interest rates can be noticed easily. For example, the estimated interest rate elasticity of house prices ranges from -0.02 to -7.1. The former figure comes from Annett (2005) for eight Euro-area countries during the period from 1970 to 2003 and the latter one is estimated in OECD (2004) about Netherlands during the period 1970 through 2002.[4]

This huge discrepancy between the estimates of elasticity are possibly caused by differences in sample period and countries, empirical models, and explanatory variables. Furthermore, some of the empirical models used in the literature lack a sound basis for the causal chain between house prices and the variables in an empirical model. To take an example, Drake (1993) selects income, mortgage rates, housing starts as explanatory variables in the regression equation without any discussion as to whether the choice of variables is plausible. To give another example, Sutton (2002) includes stock prices among the variables in a VAR model. The finding is that stock price fluctuations are as important as GNP (Gross National Product) and interest rates in explaining house price variations. However, there hardly exists any robust evidence for the interrelationship between stock and house prices except for a certain level of correlation and even the correlation can be driven by a common factor. Considering that the choice of explanatory variables may distort or misrepresent the unknown true effects of interest rates on house prices, it is necessary to examine the robustness of resulting empirical results.

Turning to the theoretical literature on the relationship between interest rates and house prices, the reasoning related to the user cost of housing lends firm support to the channel through which interest rates exert negative influences on house prices; see Mishkin (2007) and Edge *et al* (2010). Poterba (1984) derived the concept of the user cost of housing from the neoclassical type of investment model formulated by Jorgenson (1963). Still, theoretical considerations to date are short of shedding light on the issues of what are the main drivers

[4] OECD is the acronym for Organization for Economic Cooperation and Development.

of house prices and whether interest rates are more important than other factors.

Considering the limitations of the foregoing empirical findings in answering the query of whether interest rates have been the most forceful driver of house price fluctuations, my aim in this chapter is to provide another contribution in this analysis. There are two notable aspects making this chapter distinct from previous empirical research.

Firstly, this chapter provides an elaborate explanation about the causal relationship between house prices and its usual candidate determinants through extensive reviewing existing theoretical and empirical findings. It also summarizes three existing approaches to housing market equilibrium and empirical methods used in the field of housing research.

Secondly, the empirical analysis in this chapter focuses more on the volatile components latent in house prices to evaluate the role of each determinant in generating house price volatility. Deviations of actual house prices from long-term trend, extracted by Hodrick-Prescott (HP) filter, are regressed on the relevant variables identified by close review of existing empirical studies. In contrast, past empirical studies have tried to explain the overall vicissitude of house prices using the *level* or *growth rate* of house price while using an equilibrium approach to the housing market and its derivative house price equations. Exceptionally, Agnello and Schuknecht (2011) regresses the probability of the housing booms and busts on the determinants of the phenomena. To explain in more detail, they first identify the determinants[5] of the booms and busts in industrialized countries and in the next stage measure their impacts on the probability of the events. One notable common aspect exists between their approach and that used in this chapter. The dependent variable in the regression equation is not the level of house price but separate information extracted from house prices to discern the abnormal phases of the housing market. The dependent variable is the cyclical components of house prices in our analysis while it is the probability of occurrence of booms and busts in Agnello and Schuknecht (2011).

[5] The determinants are growth in per-capita real GDP, the level of short-term interest rates, the growth rate of real credit to the private sector and the growth rate of working-age population.

The structure of this chapter is as follows. In the next section, I will provide theoretical reasoning about the causality between the price of housing and its determinants and review the related empirical findings. In Section 2.3, previous empirical approaches are surveyed first and a regression model for analysis is specified. Section 2.4 provides the results of the empirical analysis. Section 2.5 is sets out my conclusion.

## 2.2 House Price Determinants

The determinants of house prices to be examined in this section include only demand-side factors based on the assumption that the housing market is driven mainly by demand rather than supply. This assumption derives from theoretical and empirical findings presented below. Based on these findings, the proposition that equilibrium is determined mainly by the demand side is judged to best befit the characteristics of the housing market although different views exist.[6]

### 2.2.1 Survey of Different Approaches to Housing Market Equilibrium

Before house price determinants we will survey below, it is worth surveying the various approaches to the concept of equilibrium in the housing market. The approaches are categorized into three types: the *supply-demand approach*, *equilibrium price approach* and *demand-only approach*. [7]

[6] In contrast with the equilibrium approach, there have been attempts to explain house price movements by the disequilibrium approach such as Fair (1972).

[7] There can be a fourth approach to defining equilibrium price utilizing the asset market equilibrium condition. This condition requires that the marginal cost, i.e., user cost of owning a house, be equal to the marginal benefit of housing services, equivalently, that the return on housing investment should be the same as that on other asset investments as Poterba (1984, 1991) states. However, since the user cost is virtually a function of housing demand factors (to be explained in detail later), the asset market equilibrium approach can be regarded as a variant of the *demand-only approach* elaborated in this section.

#### 2.2.1.1 Supply-Demand Approach

The *supply-demand approach* originates from earlier endeavours to model the owner-occupied housing sector using the general framework of supply and demand. As in Hendry (1984), this approach specifies first the demand and supply functions of housing. The main argument of these functions is lagged house prices. Then the equilibrium relationship is derived by equating demand and supply, and subsequently the housing price is defined as a function of housing price determinants. DiPasquale and Wheaton (1994) summarize the traditional form of the stock-flow approach for the residential housing market as below in which the housing supply function is defined as a differential equation.

$$\begin{aligned} D &= D(X_1, HP, U, R) \\ \Delta S &= C(X_2, HP) - \delta S \end{aligned} \tag{2.1}$$

where $X_1$ and $X_2$ are exogenous factors to the housing market. $HP$, $U$ and $R$ stand for housing prices, financing costs and rents respectively. $\delta$ denotes the rate of depreciation. The equilibrium price is determined by equating demand and supply $D = S$.[8]

$$HP = f(X_1, X_2, U, R) \tag{2.2}$$

Adams and Fuss (2010) provide a more specific example to help understand this process. In the paper, demand and supply functions are specified to elicit a regression model. Housing demand equation is defined as a function of house price ($HP$), economic activities ($EA$) such as consumption and industrial production, and long-term interest rates ($i$).

$$D = \alpha - \beta_1 HP + \beta_2 EA - \beta_3 i + \varepsilon \tag{2.3}$$

[8] In practice, the data on the quantity of supply can be obtained from housing stock statistics while the data on the demand for housing is not available. Hence, equating demand and supply means making the quantity estimated from a defined demand function equal to housing stock statistics. An example is presented on pp. 15 of DiPasquale and Wheaton (1994).

Supply is determined mainly by $HP$ and construction cost ($C$).

$$S = \eta + \gamma_1 \, HP - \gamma_2 \, C + v \tag{2.4}$$

Solving the two equations above for house price delivers the following housing price function.

$$HP = \tilde{\alpha} - \theta_1 \, i + \theta_2 \, EA - \theta_3 \, C + \tilde{\varepsilon} \tag{2.5}$$

where $\theta_1 = \frac{\beta_3}{\beta_1+\gamma_1}$, $\theta_2 = \frac{\beta_2}{\beta_1+\gamma_1}$, $\theta_3 = \frac{\gamma_2}{\beta_1+\gamma_1}$.[9]

#### 2.2.1.2 Equilibrium Price Approach

The second approach to housing market equilibrium is termed the *equilibrium price approach* since it specifies directly an equation for equilibrium house prices by employing past empirical findings instead of deriving it from the supply and demand functions. As Capozza *et al* (2004) succinctly expresses, this approach is based on the assumption that there is a stable relationship between equilibrium house prices ($P^*$) and a vector of exogenous variables ($X$) as follows.

$$P^* = P(X) \tag{2.6}$$

This assumption is embedded in the equilibrium models in numerous empirical studies, *inter alia*, Abraham and Hendershott (1996) and Malpezzi (1999). Especially the empirical research using the cointegration model, for instance Annet (2005), can be considered to adopt this approach implicitly. Notably the point distinguishing the *equilibrium price approach* from the *supply-demand approach* is that the house price equation is *a priori* defined by virtue of the past empirical findings while omitting this prior step for specifying the supply and demand functions of housing. Moreover, this approach differs from the *demand-only approach* to be

[9] The signs of several coefficients in the equation (3) and (4) can be opposite. For example, the sign of the coefficient of house price in demand function can be positive if expectation about future housing price exerts substantial power at the special phase of housing cycle. On the supply side, construction cost may not influence housing supply since the main interest of suppliers lies in the profit rather than cost.

described below in that the vector of exogenous variables $X$ in the equation (2.6) includes supply side factors such as construction cost. The advantage of this approach lies in that it can provide a benchmark level of house price which can be used to assess whether there is any deviation of the actual price from the estimated equilibrium. On the other hand, it is vulnerable to the criticism that the choice of variables can be arbitrary to secure a statistically significant equation while neglecting theoretical foundations. As a consequence, the estimated equilibrium prices can differ considerably from the unknown *true* equilibrium level. In other words, there is no proper measure for checking the robustness of estimation results because the equilibrium level is inherently unobservable.

#### 2.2.1.3 Demand-only approach

The last way of finding an equilibrium of the housing market is the *demand-only approach* which pays special attention to low price elasticity of housing supply in the short-term mainly because the minimum time required for planning and construction takes years as noted by Zhu (2005). The rigidity in housing supply arises from the peculiar properties of the housing market summarized as follows.

> They are illiquid, investments are heterogeneous in the extreme (physically but especially with respect to location), transactions costs are large, information is particularly costly, and as a rough approximation every household consumes a housing unit whether its members think housing a good investment or not. (Malpezzi, 1999; pp. 30)

> The supply of property is intensively local; delivery of the new stock can take quite a long time owing to the length of the planning and construction phases; rents can be very sticky because of the use of long-term rental contracts; market prices lack transparency and most transactions occur through bilateral negotiations; the liquidity of the market is constrained because of the existence of high transaction costs; borrowers rely heavily on external finance; real estate is widely used as collateral; and short sales are usually not possible. (Zhu, 2005; pp. 10)

Even though factors such as zoning regulation, land availability and the attitude of housing suppliers towards risk can affect the extent of supply rigidity, they are not that influential. Rather the high level of dependence on external financing in addition to the inherently large scale and irreversibility of residential investment prevent construction companies from acting preemptively. Thus, these factors are the essential reasons for the inelasticity of housing supply which causes an inevitable time lag in matching demand and supply and hence disequilibrium in the housing market. Several empirical findings lend firm support to this view. Bramley (1993) clarifies that the supply of housing responds sluggishly to the house price change in the U.K. and Meen (1996, 2002) find that the estimates of elasticity reported in British studies are less than one.[10] Taking this one step further, Barker (2004) argues that the proposition that the response of housing supply to price changes is slow and weak has been accepted without doubt among researchers. However, there exists evidence to the contrary. Topel and Rosen (1988) report the estimate of the elasticity of housing supply in the U.S. as 1.68 in one quarter and 2.76 in the long-run which is much higher than the estimate of 1.2 by DiPasquale and Wheaton (1994).[11] Malpezzi and Maclennan (2001) report a broader range of the supply elasticity between 6 and 13 for the U.S. during the post-war period. However, irrespective of differences in the levels of the estimates in the U.S., it is an undisputed fact that housing prices rose appreciably despite the huge expansion in supply as Woodward (1991) points out. That implies demand predominates over all market fluctuations.

Following the above reasoning based on the inherent features of the housing market and supportive evidence, it seems more plausible to assume that the observed level of housing price, be it equilibrium or disequilibrium, is determined significantly by factors affecting housing

[10] The sources of the estimates are not identified in the paper.

[11] We can cast a doubt on the validity of the following baseline model in Topel and Rosen (1988)

$$I_t = \beta_0 + \beta_2 P_t + \beta_3 y_t + v_t$$

where $I_t$ denotes new house starts, $P_t$ is real house price and $y_t$ is a set of cost shifters such as interest rates, expected rate of inflation, wage and construction period. In the model, housing investment is determined by house price of the current quarter which is far from the reality in that the decision of investment follows house price change with time lags. Furthermore, it is possible that the omission of lagged price variables implies that the error term $v_t$ positively correlated with $P_t$ and hence cause upward bias in the magnitude of $\beta_2$ which in turn unduly increases the elasticity of supply.

demand. An additional justification for the *demand-only approach* in which the elasticity of house supply is irrelevant to house price determination can be obtained by considering the actual pricing behaviour of construction companies. They lower the sale price as demand stalls in order to secure even smaller profits than in the housing boom period. This fact implies that there is a large latitude for these companies to adjust prices depending on the level of demand. This speculation requires support from separate empirical studies probing into the relationship between the historical profit rates of the construction industry and changes in the demand for housing.

The *demand-only approach* can be divided into two sub-categories according to whether the quantity demanded is included as an independent variable in the equation for the house price. In the *inverted demand function approach*, coined by Muellbauer and Murphy (2008) and employed by Muellbauer and Murphy (1997) and Cameron *et al* (2006), the house price equation derives from the following demand function.

$$\mathrm{log}H = -\alpha\,\mathrm{log}HP + \beta\,\mathrm{log}y + Z \tag{2.7}$$

where $H$ denotes housing stock, $HP$ is real house price, $y$ is real income and $Z$ is other demand shifters. House price equation can be derived as follows by solving the above equation for $\mathrm{log}HP$.

$$\mathrm{log}HP = \frac{\beta\mathrm{log}y - \mathrm{log}H + Z}{\alpha} \tag{2.8}$$

The other type of *demand-only approach* specifies directly the house price function as a set of exogenous variables influencing housing demand.[12] For example, in the house price equation of Iossifov *et al* (2008) below, independent variables are real economic variables such as real GDP ($y$), interest rates ($i$), inflation ($INF$), fiscal balance ($G$) and money growth ($M$).

$$HP = f(y, i, INF, G, M) \tag{2.9}$$

[12] This type of the *demand-only approach* is termed as the *direct specification* for convenience.

Comparing these two kinds of the *demand-only approach*, the *inverted demand function approach* appears to be more convincing than the *direct specification* which is the second type of the *demand-only approach* in that the former is firmly based on the demand theory. However, the awkward aspect of applying the *inverted demand function approach* to practice is that the quantity demanded is not observable. That leads researchers to use housing stock data as a proxy for the demand for housing. Conceptually, the quantity demanded means the maximum amount which consumers are willing to buy for a given level of price. In light of the definition, the actual level of housing stock in an economy may not be a good indicator for housing demand at a certain time period when the market is in an unstable state. Housing stock should instead be interpreted as the amount of housing already supplied without retaining any relation to the demand for housing. Furthermore, the demand itself is also the function of exogenous factors in the two-dimensional demand curve framework and accordingly it is possible to specify the house price function only with exogenous factors while neglecting the quantity demanded. All in all, the *direct specification* can better represent house price dynamics and is more practical because it avoids the difficulty of measuring the quantity demanded.

If the *demand-only approach* is accepted as an appropriate tool for describing housing market equilibrium, the question arises as to which variables are more influential relative to others in house price determination. The potential influential factors are, to enumerate all, interest rates, expectations of future house price, income, inflation, demographic change, credit availability and regulation, taxation on transactions and ownership, return on other assets and additional psychological factors. Among the aforementioned candidates, the first six factors will be discussed in detail to set up an effective strategy for identifying the determinants of the housing cycle.

Before entering the main discussion, it is worth paying attention to the dual aspect of housing in order to better understand the house price dynamism. Obviously housing is considered as a necessity for everyday living regardless of whether it is owner-occupied or rented. In that sense, it shares the general properties of other consumption goods, especially durable goods. On the other hand, housing is considered to be among the major investments by the majority of investors for acquiring capital gains while forsaking potential gains on alternative investments. Because of this use of housing as an investment, it is crucial to consider expectational factors and the interaction between expectations and other economic variables.[13]

### 2.2.2 Interest Rates

#### 2.2.2.1 Channels running from interest rates to house prices

In light of the practice that houses are purchased mainly by using borrowed funds such as bank lending against housing as collateral, interest rates are the most important single factor influencing the future cost of owning a house if the level of future disposable income flow is fixed. Doubtless lower interest rates increase housing demand. Kearl *et al* (1976) identifies three channels of the interest rate impact as real interest rate effect, monthly payment effect, and the effect of expectations about future interest rates. Later, the idea was modified and formulated theoretically based on the neoclassical asset market pricing approach. As stated already, Poterba (1984) was the first to create the concept of the user cost of owner-occupied housing. He highlights the aspect of housing as an asset by applying the concept of the user cost of capital to housing.[14] In that paper, the user cost is defined as a fraction of the real house price and the fraction consists of the following arguments.

$$w = [(1-\theta)(i+\tau_p) + \delta + m - \pi^e] \tag{2.10}$$

where $\theta$ denotes marginal tax rate for home ownership, $i$ is mortgage interest payment on the one hand and the opportunity cost of investment in housing on the other hand, $\tau_p$ is

[13] Case and Shiller (1988, 2003) report that the absolute majority of responders answer positively to their survey question asking whether housing is an investment. Table 6 on pp.35 in the former paper and Table. 8 on pp. 322 in the latter one include the survey results.

[14] Applying the concept of the user cost of capital in the neoclassical investment theory to housing research was initiated by Hendershott and Slemrod (1983) but formal incorporation of the concept of asset market equilibrium into a house price equation starts from Poterba (1984), as far as I understand.

property taxes, $\delta$ is after-tax depreciation, $m$ is repair cost and $\pi^e$ is expected capital gain on the housing structure.[15] Obviously, increases in interest rates raise the level of the user cost and hence decrease the demand for housing.

The aforementioned user cost effect caused by interest rate changes represents the traditional standard channel running from interest rates to the demand for housing. However interest rates have been perceived to exert further influence through extra channels than is conventionally expected and its multidimensional influence has been overlooked by existing studies. These extra channels are classified into three categories: *expectation channel*, *risk-taking channel* and *bank lending channel*.

- **Expectation channel**

  As in the period of house price appreciation during the first seven years of this century, it has become common knowledge that the lowering of interest rates results in a decrease in the cost of borrowing which leads to an expansion of the demand for housing and eventually house price appreciation. In that situation, the forecasted interest rates for the next period, alongside the observed growth rates of house prices, play a key role for housing market participants in revising expectations about the future developments of the housing market. In turn, the participants adjust their demand based on the updated expectations. For example, if the central bank lowers its target rate by 0.25%p in the midst of a housing boom, this can signal that future housing demand will be more robust or at least the same as it is currently. On the other hand, taking an extreme assumption, if the Fed had increased its target rate by, say, 3%p, optimism might have evaporated rapidly. The influence of interest rates on house price levels via affecting the public's expectations of housing demand has been underlined only recently by Mishkin (2007) and Boivin *et al* (2010). This channel has not been modeled in a theoretical

[15] In Poterba (1991), the risk premium($\alpha$) required on an asset with the risk characteristics of housing is added to the right hand side.

$$w = [(1-\theta)(i+\tau_p) + \delta + \alpha + m - \pi^e]$$

This original formula takes variant forms as in Himmelberg *et al* (2005), Girouard *et al* (2006) and Mishkin (2007) for pedagogical and practical reasons.

version and neither has it been verified empirically mainly because of the difficulty in measuring the expected level of house prices. However there is no denying its existence since the observed behaviour of home buyers is the strong evidence for it. The caveat to the *expectation channel* of interest rates is that whether this channel takes effect or not depends on the state of the overall economy and housing market. The housing market situation after the sub-prime crisis exemplifies this qualification. Even though the Fed decreased the policy rate to a level close to zero lower bound in response to the ongoing economic recession, housing demand has instead dwindled appreciably. It implies that real economic activities, the liquidity of financial markets and overall housing market sentiment are given more weight than interest rates.

- **Risk-taking channel**

  It has been pointed out that low interest rates for a continued period in the boom phase of the housing market weakened the risk-aversion of economic agents and brought about moral hazard of not only investors but also banks. For home buyers, the low level of opportunity cost relative to expected capital gains during that period might result in their underestimating future risks to housing prices and hence riskier investments. Financial intermediaries were more likely to neglect the default risk of borrowers on mortgages in the presence of house price inflation as collateral value was forecast to continue to increase. Additionally, from the perspective of portfolio adjustment in a low interest rate environment, housing-collateralized lending could be deemed the most profitable investment among the safe class of assets.The effect of interest rates on housing prices through banks' portfolio adjustment will be separately elaborated on below by the *bank lending channel.*

  Furthermore, it is worth noting that a kind of myth has grown among the public that the central bank would respond by lowering interest rates lest backlashes from the housing market crash should subdue economic growth. The myth is based on the public's observations of the actual behaviour of monetary policy decisions by the Fed which apparently reacted by lowering policy rates amid the burst of the so-called *tech bubble*. As can be noticed from ECB (2005), Trichet (2005) and Papademos (2006), the policy makers in the ECB officially warned that an asymmetric approach to asset market fluctuations may feed the belief about downward rigidity of asset prices and hence foster overly risk-taking attitude in the boom period. However, this channel has received relatively less attention and few research findings exist, and hence still needs to be verified by future empirical studies.

Only recently, Borio and Zhu (2008) began paying explicit attention to this channel in the context of monetary transmission mechanism. They define the *risk-taking channel* as the influences of policy rate changes on risk-tolerance and risk-perception. The effects from the channel affect portfolio composition, asset pricing and lending standards. Fortunately, indirect evidence can be found. Research carried out on the observed changes of the lending criteria of banks shows that deterioration in lending standards during the low interest rate environment in the last decade is associated with the effects generated through the *risk-taking channel* on the risk perception of banks. Chapter 3 will summarize the related empirical findings.

- **Bank lending channel**

  This channel is based on the observation that banks facing a dearth of objects to invest in during the low interest era expanded housing-collateralized lending. Commercial banks relaxed lending criteria and as a result enabled potential buyers facing borrowing constraints to afford houses as observed during the housing boom period before the sup-prime crisis. In my opinion, the need to adjust portfolios during the era of low interest rates necessarily entailed deterioration in lending behaviour. The logic is as follows. Lower interest rates increase liquidity and subsequently the debt of commercial banks as the increased liquidity flows into bank deposits. As a result, banks need to decide where to invest the increased balance on the debit side among, to put it simply, the three investments of bonds, stocks and lending. Banks tend to minimize exposure to risky assets such as stocks to satisfy minimum capital requirements and to be prepared for unexpected deposit withdrawals. Hence, the exposure to stocks is rigorously circumscribed. Bonds are the most unattractive investment in terms of profitability since the price is already high. The most promising investment is lending with collateral since banks can hedge against default risk by receiving collateral while the interest margin between deposit and lending is higher than the yield of bonds such as the Treasury Bill. To increase relatively safer and at the same time more profitable asset, banks wage aggressive campaigns for expanding mortgages. The fierce competition leads to easing lending criteria, lowering lending rates and supplying more favourable terms such as an exemption from transaction fees. Consequently, potential buyers who would not otherwise afford a house are able to enter the housing market, which in turn adds to the total demand for housing. Thus if lending standards are liable to deteriorate as interest rates decrease, lower interest rates stimulate a demand for housing still further. The caveat is that certain preconditions, such as the robust growth of house prices and income, should be satisfied in order for low interest rates to be transmitted through this channel.

This line of reasoning about the *bank lending channel* is based on my own observations of the actual behaviour of the commercial banks in Korea. Accordingly, it requires support from future empirical analyses of the relationship between the interest rate level, changes in the ratio of house-collateralized lending in the overall portfolio and variations in lending standards. Dell′Ariccia and Marquez (2006) suggest a theoretical framework in which banks are liable to loosen lending criteria in the presence of robust economic growth since increases in the number of unknown projects make information asymmetry less severe. More of the related empirical findings are introduced in Chapter 3. However, there also exists an empirical finding running counter to the above reasoning. Lown and Morgan (2006) assert that monetary policy shock hardly induces changes in lending criteria applicable to businesses through a VAR analysis on the metrics of bank lending standards.

Separating the *bank lending channel* from the *risk-taking channel* may seem unnecessary since the former is operating through the attitude of banks towards the risk surrounding mortgages. The sole use of the *bank lending channel* lies in that it can bridge low interest rates with credit expansion by banks' portfolio adjustments.

#### 2.2.2.2 Discussion on the relevant type of interest rate

Admitting that interest rates as a concept is one of the significant housing demand determinants, one further issue remains as to which type of interest rate in practice is more effective for explaining house price changes. There are two pairs of different kinds of interest rates: real and nominal, and short-term and long-term interest rates.[16] Regarding the first pair, there was an active debate in the 1970s regarding which plays a more influential role in changing housing demand. The background to the debate was a high rate of inflation which was a main concern not only to housing policy implementation but also to academics who attempted to solve the issue. The main issue of the debate at the time was whether the expected rate of inflation, the difference between nominal and real interest rates by the definition of Irving Fisher, can change housing demand. According to Schwab (1983), there are two competing views. The first view argues that housing demand depends on real interest rates as well as the expected rate of inflation. That view was prevalent earlier in the modeling housing demand function.[17] The second position, the monetarist view expressed in Arcelus and Meltzer (1973), values only the effect of real interest rates based on the orthodox view of monetarists that ultimately all the nominal variables increase at the same rate.

Obviously it is still moot which view is theoretically correct, but nominal interest rates have been considered to be more pertinent in the research on house price determination for the following reasons. Above all, from the perspective of the user cost of capital, Poterba

[16] There is another pair of interest rates in the practice of bank lending which are variable and fixed rate corresponding to short-term and long-term interest rates respectively.

[17] Originally Schwab (1983) suggests three views on this topic. The remaining one maintains that housing demand is the function of nominal interest rates. However, it seems to not be substantially different from the first view.

(1991) makes it clear that the interest rate as one of the user cost components is nominal. Furthermore, Lessard and Modigliani (1975) exemplifies the speculation that expectations of higher inflation tilts the stream of repayment forward even if real interest rates were constant. In terms of the reasoning, Schwab (1983) adds empirical support that the cash flow effect of the repayment schedule tilting forward caused by an increase in the rate of expected inflation affects negatively the demand of those potential home buyers facing borrowing constraints. To add my own speculation, potential home buyers tend to focus on the level of nominal interest rates specified in borrowing contracts when judging whether debt servicing is feasible based on their permanent level of nominal income.

Turning towards the second pair of short-term and long-term interest rates, the latter seems more effective for housing demand from the viewpoint of the asset pricing principle. According to this principle, the price of an asset is the sum of future cash flow emanating from owning the asset discounted by an interest rate having the same maturity as the duration of the asset. Based on this principle, Greenspan (2010) argues that the house price bubble was fostered by low long-term interest rates. Even though the reasoning is theoretically consistent, it is questionable whether the principle holds up in practice. Given that *actual* interest rates instead of ones derived from the asset pricing principle are effective in practice when deciding whether to buy a house, borrowers have the option of choosing the type of interest rate (long-term or short-term) which they perceive to be the most cost-effective. By these practical considerations, it is hardly acceptable that long-term interest rates exert more effect than short-term interest rates. Rather, the issue should be solved by allowing for the actual lending practice in which the short-term lending rate is variable while the long-term rate is fixed through the period of a contract. It can be induced from the consideration that long-term interest rates are more influential than short-term interest rates in the countries where the fixed rate is prevalent in mortgage lending.[18] However, considering the high level of correlation implying the stable term structure between short-term and long-term interest

[18] Debelle (2004) sets out the prevalent type of interest rate in industrialized countries. (pp. 58) For a more detailed version, consult Borio (1995, pp. 21, Table 9) and ECB (2003, pp. 50, Table. 5.1)

rates, the two types of interest rates are possibly interchangeable. For example, the coefficient of correlation between the monthly average of the Federal Funds Rate and 10-year Treasury Bond yield rate is 0.90 during the sample period from February 1977 to April 2010. To summarize, it appears to be more desirable to find out which type of interest rate is significant by empirical analysis rather than by concluding in advance.[19]

#### 2.2.2.3 Review of Empirical Findings about Effects of Interest Rate

As can be expected by the foregoing discussion on the effects of interest rates on the demand for housing, the coefficient of interest rates, be it long-term or short-term and nominal or real, turns out to have a negative sign and be statistically significant in the existing empirical studies.[20] Despite the consistency in the sign of the coefficient in regression models which is interpreted as the interest rate elasticity of housing price, one conspicuous difference exists among the findings. The magnitude of the coefficient from cross-country studies tends to be noticeably lower than that from individual country studies even after allowing for the differences in econometric models and variables employed. As Iossifov *et al* (2008) recognizes, the absolute value of the coefficient of interest rate is less than unity in panel approach pooling multi-country data whereas it is over three in most of the single country studies. For example, Englund and Ioannides (1997) adopt a cross-country approach. They regress the real house price changes in 15 OECD countries on the GDP growth rates, real interest rates and one period lagged values of the dependent variable. The finding is that a 1% increase in real interest rate leads to a decrease of 0.012% in real house prices. Further examples of interest rate elasticity in international studies are -0.03 from Glindro *et al* (2008) for 9 Asia-Pacific countries, -0.01 to -0.02 from Annett(2005) and -0.3 from Adams and Füss (2010).

[19] Aside from this issue, a further topic deserves notice: whether increases in adjustable rate mortgages which are closely linked to short-term rates tend to expand demand.

[20] Instead of interest rates, the user cost (including interest rates as a factor) is set as an independent variable in estimating regression equations in numerous studies and the coefficient of it turns out to be significantly high in most cases. However, the findings from the models do not have any implication for interest rate elasticity since there is no disentangling the effect of the individual factor from each other in user cost. The related literature includes Kearl(1979) and DiPasquale and Wheaton (1994) for the U.S. case, Hendry (1984) and Drake (1993) for the UK, Hort(1998) for Sweden, and Kennedy and Anderson (1994) for cross-country study.

The result from Kasparova and White (2001) is striking. They estimate the elasticity by employing not only a panel approach but also a regression analysis for four single European countries (including the U.K., Germany, Netherland and Sweden). In the resulting findings, the coefficient of mortgage interest rates in the pooled data analysis proves to be insignificant whereas it turns out to be significantly negative in the regression on Germany.

The starkest contrast in the magnitude of interest elasticity between cross-country and individual country study is found in OECD (2004) and Hofman *et al* (2005). These papers report -7.1 and -9.4 respectively as the real interest rate elasticity of housing in the Netherlands.[21] There are findings which obtain an estimate of the elasticity lower than these values; for example, -4.6 for Finland in Oikarinen (2005), and -3.5 for the U.K. and -1.3 for the U.S. in Meen (2002). The reasons for these differences in elasticities is not fully understood. Presumably, the difference arises from the inherent limitation of panel data analysis that the distinct characteristics and developments of individual housing market and financial system are diluted by pooling the data from different countries. Furthermore, the definition and compiling convention of the house price indices vary widely. The variations may distort the effect of interest rates. In this sense, the findings of single country studies may be regarded as more credible; a conjecture supported by the finding of Iossifov *et al* (2008) in which the real short-term interest rate elasticity of housing prices is estimated to be -3.6 in a *cross-section* analysis of 20 advanced countries.

### 2.2.3 Expectation

Expectation is the most elusive determinant of the demand for housing. It is primarily because there is no practical measure for it. Furthermore, economic theory seldom sheds light on the actual process of the expectation formation process, primary drivers of variations in expectation and its interrelationship with other economic variables. Undoubtedly the importance of expectation stems mainly from the characteristic of housing as an investment

[21] It can be a topic of a separate study as to why the interest elasticity in the Netherlands is far higher than that of other countries

even though the public's recognition of it started only several decades ago as Shiller (2007) argues. In this subsection, I will discuss the findings to date on the property of expectation in the housing market and then suggest a hypothesis stating that the excessive volatility of house prices unjustifiable by economic fundamentals can arise from naive and irrational expectations during the boom phase of the housing market.

The role that expectation about future house prices plays in determining the demand for housing has been highlighted mainly by empirical studies rather than by theoretical literature. The empirical studies have concentrated on checking whether the housing market is efficient, in other words, whether the participants in the housing market are rational enough to utilize all the information available to form expectations. By and large, the findings hint that the expectations of home buyers tend to be extrapolative and backward-looking rather than rational. The authentic origin of the study on non-rational expectations can be dated back to Kindleberger (1978) who scrutinized the huge volume of historical records on the abnormal volatilities observed in asset markets. He concludes "rationality is thus an a priori assumption rather than a description of the world". (*Ibid* ; pp.24).

However it was the survey research of Case and Shiller (1988) that ignited the subsequent serious studies on the actual behaviour of expectation. They presume that the protracted period of house price inflation could be driven by people's expectations to a large extent.[22] The motivation for the survey was the failure of Case (1986) in accounting for the substantial part of the increases in housing prices observed in the 10 cities in Boston by the conventional type of regression analysis. He attempted to explain the house price appreciation by employing the structural supply-demand equation including the usual macroeconomic variables as the determinants of house prices. The crucial findings in the survey research are, firstly, that the dynamics of the housing market are driven mainly by expectation based on the past record of house prices and, secondly, that the feedback loop between expectations and house price changes foster the boom. Their incipient conjectural findings appear to be valid given

[22] In my view, the literature on expectation in the housing market appears to explain the house price changes by implicitly using the disequilibrium approach rather than the equilibrium framework.

that house prices rose robustly in the U.S. during the period from 2004 to 2006 even though interest rates increased only gradually but continuously.[23] If investment in housing is a simple function of objective economic conditions, such as income and interest rates, the house price rally might have terminated after interest rates reached a certain threshold.

The ensuing studies also support their view which highlight the strong persistence of house price change and excess returns on housing (Case and Shiller, 1989 and 1990; Cutler *et al*, 1991; Meese and Wallace, 1994). Cutler *et al* (1991) emphasizes that the strong serial correlation of the excess reruns on assets is caused mainly by the investment behaviour of the so-called 'feedback traders' who determine the demand solely through consulting the past returns.[24] As Englund and Ioannides (1997) clarify, the strong serial correlation turns out to be modeled best by the first-order autoregressive model, namely $AR(1)$ process by common notation. The positive *short-term* and negative *longer-term* serial correlation has been widely accepted as the main feature of the house price time series.[25] All of these findings are summarized in the following remarks by Shiller (2007) based on the results of the questionnaire survey in Case and Shiller (1988) and Shiller (2007).

> Times and places with high home price increases show high expectations of future home price increases, and when the rate of price increases changes, so too do expectations of future price increases, in the same direction (pp. 96)

The predominance of expectations during the boom period based on the past price level of housing necessitates a correction for the standard downward-sloping curve. If the expected future house prices are so high that the rises in price fail to dampen demand, the demand can depend positively, not negatively, on house prices. For example, in the boom phase, increasing house prices can instead stimulate demand, which makes the demand curve upward-sloping.

[23] The survey results are elaborated on by Shiller (2005) and applied to the recent boom episode in the U.S. by Shiller (2007).

[24] This paper is the formal and extended version of Cutler *et al* (1990).

[25] The time period of the first order is one quarter in the paper. However, it can be one year depending on the specific frequency of the data.

The question follows as to what motivates people to purchase housing in the face of price hikes. The first incentive without doubt is for earning capital gains. If the proportion of home buyers with this incentive takes the majority, the status of housing as an investment dominates the common property of housing as non-inferior consumption goods. Dusansky and Koç (2007) present a possibility that the demand for owner-occupied housing may not necessarily be downward-sloping. The assumptions underlying the proposition are that expectations about future house prices are based only on their current level and that housing composes the total wealth. Their empirical test using the 1990 survey data of Florida in the U.S. in 2007 supports their prediction that the effects of housing prices on the demand for housing is positive.[26] The second but not less important incentive is the anxiety, as Shiller (2007) also notes, of first-time home buyers about their being priced out of the market. For these who regard it as necessary to own a house, the rising price may act as a precipitant for buying a house, not depressant. They become willing to buy homes even by borrowing a considerable chunk of purchase expenditure in the presence of rapid housing price inflation.

However, despite the considerations stated above, there still remain two important qualifications. Firstly, it can hardly be true that only past house prices are included in the information set required for forming expectations. It seems to be more reasonable to assume that the current level of other house price determinants and anticipation about the future changes in these variables also affect the expected level of house prices. Harris (1989) shows that expectation can vary by changes in interest rates since it is commonly known that interest rates negatively influence house prices. Moreover, it is argued that the recent boom episode in the housing market can be attributable in part to expectations of positive shocks to future income.[27] In light of that, the actual process of expectation formation can be better described by the duality of being extrapolative and forward-looking. To illustrate an example

[26] However the study has various limitations. Representatively a cross-section analysis is not suitable for revealing the dynamic relationship across time between demand and expectation(Ibid, pp.96).

[27] As mentioned in the Introduction, Kahn (2009) attributes the housing boom in the U.S. to a resurgence in productivity.

for this presumption,

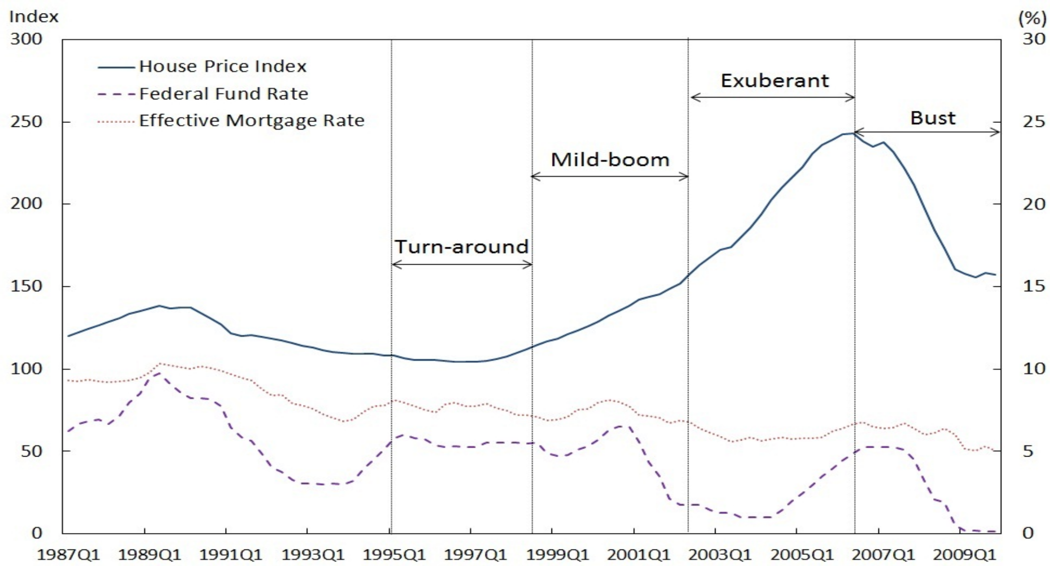
$$
\begin{aligned}
HP_t^e &= E_{t-1}(HP_t | I_{t-1}) \\
&\quad \textit{where} \quad I_{t-1} = \{HP_{t-i}, R_{t+1}^e, Y_{t+i}^e\} \qquad i = 1, 2, 3, \cdots
\end{aligned}
\tag{2.11}
$$

where $E_{t-1}$ denotes expectation operator at the time $t-1$, $I_{t-1}$ is the information set available, $R$ is interest rate and $Y$ is income level. Naturally, $I_{t-1}$ can include other variables such as taxation on transaction, demographic factor, and so forth.

The second qualification is related to the heterogeneity of expectation among home buyers and its state-dependent property. The behavioural aspects of the expectation formation process can differ widely depending on the characteristics of home buyers and simultaneously on the specific phase of house price developments. A certain group of buyers, representatively real estate investment trusts (REITs), may maintain a relatively more rational way in forecasting the future path of house prices utilizing more information available while another group of buyers who are constrained in accessing or processing the information put more emphasis on the observed level of house prices. Furthermore, in the boom period, the achieved capital gains may make even rational investors elated and complacent. In turn, the elation is more likely to translate into overemphasis on the growth of house prices while giving less weight than necessary to other variables relevant for the demand for housing. The more naive become peoples' expectations, the more distinct becomes this symptom.

Based on the above considerations, I suggest a simple idea in which different types of expectations dominate in the specific phases of the housing cycle to explain the evolution of the housing market. For simplicity, the housing cycle is divided into four phases, the *turn-around, mild-boom, exuberant and bust phase* as illustrated by Figure 2.2. Investors or home buyers are classified into three groups depending on the adopted type of expectation among *rational, adaptive*, or *naive forms*. For convenience, each group is termed as the *rational*, *adaptive*, or *naive group* following the main type of expectation of each group. The notable point in the group division is that the members of each group vary depending on the phase of the housing cycle. For example, a rational investor can turn into a naive one during the overly heated period of the housing market.

**Figure 2.2. Phases of Housing Cycle in U.S.**




Data Source: Federal Reserve, Standard and Poor's Case & Shiller Index

During the phase coming out of the trough, the demand for housing is driven mainly by the investors who expect house prices to increase through estimation results from an econometric model employing almost all the available information. As such, the *rational group* ignites the rally to the full-blown boom recognizing the favourable objective conditions for the upturn of the housing market such as ample liquidity and robust economic growth. In this initial phase, investors and buyers belonging to the *adaptive group* continue correcting the error between their forecast and observed house price levels. The weight assigned to house prices at each time point exponentially decreases as a time period becomes distant from present. At a certain time point, the *adaptive group* joins the buying rally as their forecasts of the growth rate of housing prices obtained by exponential smoothing are positive enough for investment. By the increased demand from that group, the *Mild-boom phase* begins. As the house price rally continues, the investors who focus only on a relatively higher return on housing or the first-time home buyers who are anxious about housing becoming less affordable in the future finally enter the market and accelerate the speed of house price appreciation. The necessary

**Table 2.1. Housing Cycle and Expectation**

| | Dominant Expectation Model and Symptoms |
|---|---|
| Turn-around Phase | • **Rational Expectation**<br>$HP^e_t = E_{t-1}(HP_t \mid I_{t-1})$<br>· Recognition of positive signals from objective conditions such as:<br>- Low interest rate<br>- Robust economic growth<br>· Wider set of information utilized |
| Mild-boom Phase | • **Adaptive Expectation**<br>$HP^e_t = HP^e_{t-1} + \lambda(HP_{t-1} - HP^e_{t-1}) \Leftrightarrow HP^e_t = \lambda \sum_{i=0}^{\infty} (1-\lambda)^i HP_{t-i-1}$<br>· *Adaptive group* joins the buying rally<br>· House price growth accelerates<br>· Ample liquidity and higher credit availability |
| Exuberant Phase | • **Naive Expectation**<br>$HP^e_t = \lambda HP_{t-1},\ \lambda \geq 1$<br>· Excessive weight to house price growth in forming expectation<br>→ overriding negative signals from objective conditions<br>· Members of other groups also follow naive model<br>· Anxiety drives first home buyers into buying rally<br>· Negative signals from objective conditions ignored<br>- Interest rates increase<br>· Forced selling begins because of worse economic conditions<br>· *Rational group* starts realizing capital gains |
| Bust Phase | •**Rational Expectation**<br>· High weight to house price changes in forming expectation<br>· Unfavourable objective conditions recognized<br>- Lending standards tightened<br>- Foreclosures increasing<br>· Negative sides of economic circumstance override positive signals |

condition for their participation is easy access to loans to enable them to fulfill their naive expectations. In this *Exuberant phase*, the immense scale of capital gains encourages a portion of the *rational group* to 'ride with the bubble'. Especially, the negative signals for the housing market transmitted by a deterioration in objective economic conditions are neglected by overly optimistic forecasts based mainly on the current growth rate of house prices. The most recent example for the symptom can be found in the housing boom period from 2004 to 2007 during which house prices continued appreciating amid monetary policy tightening. Basically, the belated response of house prices to negative signals originates from the strong inertia of naive expectations. If the common naive expectation model $HP_t^e = HP_{t-1}$ is slightly modified, it can be expressed as follows.

$$HP_t^e = \lambda \cdot HP_{t-1} \tag{2.12}$$

The level of $\lambda$, termed the *reaction factor*, remains over one in the *Exuberant phase* as only the recent growth rate of house prices enters into the information set. Only the *rational group* disposes of the houses they own and realize potential capital gains. Their sales pressurize the housing market downward. On the other hand, the group of owners vulnerable to the changes of objective conditions, for example, highly leveraged buyers, faced with the burden of having to service interest rates on a large scale, resell houses to repay the debt. The growth rate of house prices decelerates appreciably and at last a housing cycle reaches its peak. The next phase, the *Bust phase*, is driven mainly by the rational form of expectations. As the market returns to normality, the participants become aware of the negative signals from new economic circumstances and subsequent aftermaths. In this phase, previously loosened lending standards are tightened once again as a proportion of borrowers fail to refinance and in extreme cases default on their mortgages because of decreases in the value of collateral. Foreclosures are increasing and such *shadow inventory* dampens the housing market further. Market participants with the intention to buy houses expect further depreciation not only from naive expectations but also from a sober recognition of the worsening objective situation. However, the speed of depreciation is curbed since there always exist people who buy homes for their own use and bridge the gap to some extent between demand and supply.[28]

### 2.2.4 Income

Unquestionably, income is among the most important determinants of the demand for housing since increases in income enhance affordability of housing, i.e., the ability to repay debt

[28] For the purpose of simplicity and clarity, this hypothesis on the heterogeneity of expectation needs to be modelled theoretically by further research. The idea of the *noise trading* established in the analysis of financial assets can shed light on this theoretical modelling.

principal and interest specified in a contract of borrowing. This proposition is as lucid as the common knowledge that consumers' purchasing power of and demand for consumption goods increase with income growth. For that reason income has been considered to be an indispensable regressor in the regression equation for housing demand without any further theoretical consideration. Only the issue of which definition of income is appropriate in explaining house price fluctuations has been raised. Until now, there has been consensus on the issue. Firstly, the concept of income should be *disposable* instead of *gross*. Secondly, the *median* level rather than the *overall mean* of income per capita is more pertinent since the income level of these who own a house has been proven to exceed the average in most countries.[29] Thirdly, there seems to be no objection to the view that income should be *real*, not *nominal*. Nevertheless, one can pose the question whether there exists a kind of money illusion on the part of home buyers. They tend to pay more attention to nominal income because they observe first nominal house prices without bothering themselves with discounting them by the overall price level to calculate real house prices.

As regards the related empirical findings, the income elasticity of house prices, if extreme cases are excluded, ranges from 1 to 3 without no systematic difference between cross and single country studies.[30] The frequently cited estimates of income elasticity are 2.5 and 2.7 for the U.K. and U.S. in Meen (2002), 1.7 for the U.K. in Muellbauer and Murphy (1997). In OECD (2004) and Hofman *et al* (2005), the estimates are 1.9 and 1.5 respectively for Netherlands. Oikarinen (2005) reports 1.2 for Finland. Although there is no established explanation about the variation of income elasticity among these countries, Meen (2002) suggests the different level of housing supply elasticity as one possible reason. The simulation results appearing in the paper show that the income elasticity plummets as supply becomes more elastic. An additional noteworthy observation comes from Hort (1998) that there exists a dichotomy between the two groups of countries. In one group which the U.K. and Denmark belong to, the estimated elasticity ranges from 2 to 4, and it is nearly or below that for the

[29] A practical difficulty in implementing the consensus is that the median income level data are compiled on an annual basis while the frequency of other data for other determinants is monthly or quarterly.

[30] Annett (2005) reports the pooled income elasticity as 0.1 to 0.4 for European countries.

other group including the U.S. and other Nordic countries. However late empirical research calls the existence of the dichotomy into question and contradicts any coherent chasm between the two groups of countries.

### 2.2.5 Demographics

The forecast of the rapid fall in the rate of house price inflation in the U.S. between1987 and 2007 by Mankiw and Weil (1989) and the coincident decrease in real house prices commencing from 1987 funneled the interests of researchers into demographics and provoked the intense debate on the influence of demographic changes on house price fluctuations. Their logic underlying the forecast was accepted as persuasive in the first instance. They argue that firstly, the demand for housing is substantially high with the population cohort belonging to the household formation age of 20-34, secondly, the demand is closely correlated with house price changes, and lastly, as a consequence of the dwindling population at the age cohort will decelerate the growth rate of house prices. Despite apparent plausibility, the argument was immediately followed by criticism mainly aimed at the misspecification problem in the regression model in the paper. Hamilton (1991) points out the problem of including the time trend in the regression equation without specifying an underlying demand-supply equation. Woodward and Hendershott(1991) maintain that the main problem of the regression model was omission of expected capital gains as an explanatory variable. Engelhardt and Poterba (1991) apply the same model used by Mankiw and Weil to Canada which experienced the robust growth in housing prices in the 1970s with a similar demographic structure to the U.S. case. They find that the forecasted extent of the decrease in house prices is fairly moderate compared with that of Mankiw and Weil (1989). Moreover, they point out the possibility of the spurious relationship between housing prices and demographic changes caused by the non-stationarity of these two variables.[31] Lastly, Peek and Wilcox (1991) suggest no evidence for the influence of demographics on house prices during the period from 1970 to 1984 in

[31] All of these commentaries are included in *Regional Science and Urban Economics* vol.21 (1991) and the rejoinder by Mankiw and Weil followed in the same volume published in 1992.

which the growth rate of house prices was pronounced. The similar line of that conclusion was followed by Englund and Ioannides (1997) and Muellbauer and Murphy (1997).

With hindsight, the original forecast of Mankiw and Weil (1989) seems inconsistent with the actual path of house prices in the U.S. which shows an upward trend during the period from the late 1990s to 2008. The essential reason for the weak predictive power originates from their overemphasis on demographics in deriving the coefficient of age dummy variable in the cross-section analysis. Nevertheless, as Poterba (1991, pp. 55-56) clarifies, house prices are affected by demographic factors, representatively by the number of households. However, he argues, the timing and the magnitude of the effect are hard to predict as these factors are part of a broader set of economic forces influencing house prices. This conclusion is supported by several empirical studies showing the positive impact of the demographic variable on house prices (Green and Hendershott, 1996; Agnello and Schuknecht, 2011).

### 2.2.6 Inflation

During the inflationary period of the 1970s and early 1980s, the relationship between inflation and the demand for housing was underscored as it was the main assignment for researchers to elucidate the influence of accelerating inflation on housing prices. However, the heated interest in inflation as a determinant of housing demand dissipated rapidly after the 1990s, which reflects the fact that inflation has been kept in a reasonably predictable range characterized by the term 'Great Moderation'. Recent studies appear not to consider it as seriously as in the inflationary era. Still, it is worth taking a glimpse of conflicting views and empirical results about the role of inflation in house price determination in that the topic is closely related to interest rates and expectations. Different from other determinants, there is no established consensus on whether inflation increases or reduces housing demand. This divergence has been mainly caused by different approaches to the housing market and varying weight assigned to the individual factor of the cost of owning a house. Lessard and Modigliani (1975), as mentioned in subsection 2.2.2, present the simulation result that the real payment of mortgage is tilted forward under inflation in tandem with rising nominal interest rates and the tilting intensifies as inflation accelerates.[32] Nevertheless, the total sum of the real cost to borrowers is constant irrespective of the rate of inflation and hence it cannot affect the buying decision of the buyers without financial constraint.

However, households with low income and under borrowing constraints, for instance younger households, can postpone or withdraw a purchasing decision in the presence of a ballooning burden to repay in the initial period of a borrowing contract. Kearl (1979), reflecting this consideration, inserted the term for initial payment sensitive to inflation into the conventional housing demand function which includes the user cost of owning a house as a main argument. Through regressing the time series of house prices on the demand determinants, he finds that the coefficient of initial mortgage payment, which is also the function of nominal interest rates, is negative and statistically significant for the U.S. data from 1961 to 1973. Moreover, from the same motivation, Schwab (1983) obtains the negative coefficient of expected inflation in the house price regression using the microeconomic data for Philadelphia in the U.S. from 1968 to 1975. Besides the initial payment effects, Kearl (1979) adds another noteworthy reasoning about the depressing effect of inflation on the demand for housing. While nominal interest rates reflect inflation relatively swiftly, nominal income is somewhat rigid and hence the delayed response of income to price change diminishes the demand for housing by making housing less affordable to potential buyers.

The opposite view maintains that inflation stimulates the demand for housing by lowering the user cost in real terms. This argument is based on the assumptions that agents have a perfect foresight and a steady state exists in the economy. This view is inconsistent with the practical considerations and empirical results provided in the preceding paragraph. Poterba (1984) formulates the user cost of housing utilizing the asset-market approach and derives the partial derivative of the user cost with respect to inflation. In the steady state condition requiring that the growth rate of nominal house prices should be identical to the overall

[32] The tilting effect arises as the discount factor for flat annual nominal payment exponentially rises rapidly.

inflation rate, the sign of partial derivative is negative under a specific condition. To state this more specifically, if both sides of the user cost equation (2.10) below are differentiated,

$$w = [(1-\theta)(i+\tau_p) + \delta + m - \pi^e]$$

the equation below derives.

$$\frac{dw}{d\pi} = (1-\theta)\frac{di}{d\pi} - \frac{d\pi_H}{d\pi} \tag{2.13}$$

Because $d\pi_H = d\pi$ in the steady state, if $\frac{di}{d\pi} < \frac{1}{(1-\theta)}$ making $\frac{dw}{d\pi} < 0$, inflation shock can increase the quantity demanded by decreasing the real user cost defined as $w \cdot HP$ in which $HP$ denotes real house price. He argues that if the marginal tax rate, $\theta$, is 0.25 and nominal interest rates rise by less than 1.3%p for 1%p increase in the inflation rate, the inequality always holds. The simulation results predict that real house prices appreciate by 13.6%p responding to 5% rate of inflation. This finding is contrary to the empirical findings above highlighting the initial payment effect. Apparently, this stark contrast arises from the assumption about elastic supply and rational expectations, and also from the restriction on the changes of nominal interest rates corresponding to inflation.

Another line of reasoning supporting the positive influence of inflation on house prices is based on the common knowledge that people tend to invest more in *real* assets to hedge against decreases in the purchasing power of *nominal* assets caused by inflation. Evidently, housing is a real asset and inflation has a positive effect on the demand for housing. However, without empirical findings to verify whether this common knowledge is valid or not, the plausibility of the speculation is strictly circumscribed in that only a limited fraction of all home buyers have financial means to realize the incentive to hedge inflation risk. Additionally, the rate of inflation needs to be high enough to stimulate the demand for hedging. For example, it is not plausible that households under financial constraint would borrow substantial amounts to buy a house in order to prevent the trivial loss in the real value of their nominal income which is caused by a narrow increase in the rate of inflation while servicing interest on the funds borrowed to buy the house.

As discussed above, the direction in which inflation affects the demand for housing is left open to further investigation as the disagreement between the two competing views remains unresolved.

### 2.2.7 Credit Availability and Regulation

Generally speaking, the value of a house far exceeds the annual amount of savings of home buyers and for that reason the demand for housing depends considerably on accessibility to credit or liquidity. For example, a large down-payment is necessary for buying a new house in the U.S. and the liquidity available for buyers influences the decision whether to purchase a house (Stein, 1995). No doubt the accessibility varies among individuals depending on the level of income and creditworthiness. It also varies across time as the regulations governing the financial sector evolves. Disregarding individual differences, the total demand for housing depends to a certain extent on credit availability varying with the developments of housing finance.

In the 1980s, the crucial changes in housing finance can be epitomized by the term 'liberalization' which offers wider discretion to financial intermediaries. As Iacoviello and Minetti (2003) summarize, the steps taken as a way of liberalization include abolishing the ceiling on interest rates related to deposits as well as lending, expanding the latitude to determine portfolio composition, lifting entry barriers to lending markets, and easing of restrictions on the total amount of borrowing.[33] Among the deregulation measures, Miles (1992) argues that more opportunities to employ equity withdrawal, namely, lending against the collateral of housing, represent the key feature of financial liberalization. In tandem with that, the ceiling set by regulation on the maximum loan to value ratio (LTV) has been increased in most OECD countries as Jappelli and Pagano (1994) records.[34] Another tangible result of the

[33] A more detailed description is presented in Chapter 3 of IMF (2000).

[34] Table II on pp. 92 in the paper include the LTV ratio statistics.

liberalization process might be the introduction of variable interest rates, synonymous with adjustable rates, into lending contracts. Taken together, these phenomenal changes in housing finance heighten the level of credit available to households under borrowing constraints and accordingly increase the demand for housing.[35]

After the 1990s, the second-round effects of the financial liberalization on house prices have attracted considerable attention in housing research. Kiyotaki and Moore (1997) and Bernanke *et al* (1996, 1999) argue that the influences of a shock to the economy can be amplified and also propagated through the initial changes in the value of collateral such as land. Subsequently the amplification process causes changes in the borrowing capacity of economic agents. In the same vein, the amplification mechanism can be applied to the housing market. If a positive shock hits the economy such that the demand for housing expands and consequently house prices appreciate, that leads to increases in the net worth of the collateral. As this makes equity withdrawal easier and renders the regulation on LTV looser, the capacity for buying houses becomes greater. Subsequently, the newly created demand for housing, caused by an increase in credit accessibility following the initial shock, accelerates the speed of house price inflation.

To verify whether the mechanism operates in the housing market, Lamont and Stein (1999) classify the 44 cities into the two groups of the high and low-leverage city and regress the house prices on income and the one-period lagged dependent variable over the period 1985-1994. They find that both the sensitivity of house prices to income shock and the resulting cumulative changes in house prices are higher in the case of the high-leverage city group than in the case of the low-leverage group. To generalize this finding to an international

[35] Whether there exists robust correlation between credit and house price movements and whether there is any causality running from the former to the latter are separate issues to be tested empirically. Even though consensus on the existence of the close co-movements between bank lending or credit and real asset price has been established by empirical findings, for example Goodhart and Hofmann (2004, 2008) and Gerlach and Peng (2005) *inter alia*, the issue on causality remains inconclusive. Goodhart and Hofmann (2004) find through VAR Impulse Response analysis that credit influences property prices in only a few of the twelve sample countries over the period 1985-2001. But in the ensuing paper in 2008, they provide new evidence that house prices and credit have a reciprocal effect using data from seventeen industrialized countries over the period of 1970-2006. However, Gerlach and Peng (2005) argue that bank lending appears not to influence property prices in Hong Kong based on the data from 1982 to 1998.

level using the data from 26 countries from 1970 to 1999, Almeida *et al* (2006) confirms that house prices respond more rapidly to income shocks in countries having a higher ceiling on LTV ratios. On the basis of these two findings, it can be concluded that the liberalization measures taken from the 1980s onwards have modified the way in which, and the extent to which, house prices respond to changes in the house price determinants. As is widely noted, financial liberalization is one of the sources of the greater volatility of housing observed in the last decade compared to the period before liberalization was initiated.

Despite the theoretical and empirical findings introduced above, research on the relationship between changes in credit availability caused by the institutional reforms in the mortgage market and the demand for housing is relatively nascent compared to other topics discussed in the preceding subsections. Hence, this issue requires further theoretical consideration and empirical analysis which can provide firm evidence for the way the demand for housing interacts with the evolution of housing finance.

### 2.2.8 Synthesis

The relationship between house prices and the six determinants which are supposed to be the most influential have been discussed consulting the empirical and theoretical findings to date. The interrelationships between the determinants and house prices are illustrated in Figure 2.4.[36] These determinants, assuming that house prices are determined mainly by the demand factors, change the demand for housing and hence house prices whether it be driven by equilibrium or disequilibrium.[37] Regarding the relative magnitude of the individual factor, we can draw the following propositions from the empirical findings. Firstly, interest rates and income are most important, but it is inconclusive which is more significant. Secondly, expectations

[36] This list of the influential determinants is not exhaustive especially in that the effect of taxation is omitted from the list. Without doubt, alteration of tax treatment on ownership such as interest deductibility from income tax and transaction tax (such as stamp duties) affects house prices irrespective of the magnitude of the effect.

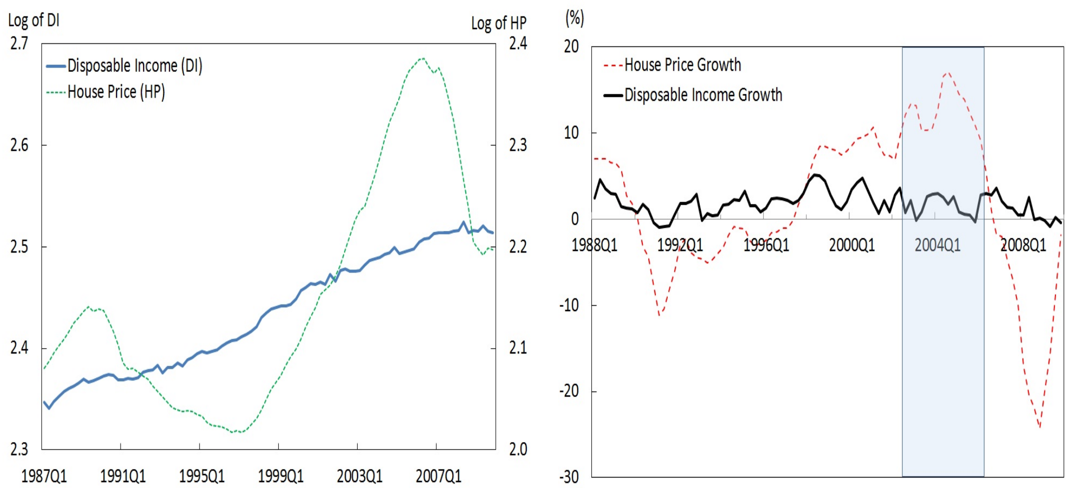
[37] For the empirical studies which consider the supply side, construction cost is included as an explanatory variable in the regression equation for house prices. However, at least from my viewpoint, the quantity supplied or to be supplied appears to be the function of house prices, more fundamentally of the quantity demanded, not construction cost.

have received muted attention relative to the preceding two factors considering its prior role in leading the housing market into the *exuberant phase*. Thirdly, credit availability is a newly highlighted factor and is claimed to have a connection with interest rates as well as with regulatory changes. Fourthly, demographics and inflation retain a certain level of influence even though the extent of the influence is deemed negligible compared to other factors. From these observations, we can provisionally conclude that interest rates, expectations and income are the key factors for explaining fluctuations in the demand for housing.

Even with the elaborate discussions above, it has not been clarified yet why the time series of house prices have shown a markedly cyclical pattern like a business cycle instead of a trend-stationary or purely stationary outlook. That question can be replaced by asking what are the underlying forces which drive the demand for housing to such an extraordinary level and induce the huge deviation of house prices from a stable path. Apparently, income appears to have the least explanatory power for explaining the drastic volatility observed in house prices. As illustrated in the left panel of Figure 2.3, the level of disposable income per capita in the U.S. has shown a stable upward trend while house prices fluctuated to a large extent around the trend-stationary path of income level. This marked distinction arises from the difference in the volatility of the growth rates of each variable. Turning to the right panel in the same figure, the 4-quarter growth rate of income has changed within the by far narrower band ranging from -1% to 5% relative to that of house prices ranging between -24% to 17%. Without the assistance of high leverage, income alone can hardly explain that high level of volatility.

The probable candidates affecting leverage, consulting the discussions on house price determinants, are presumed to be interest rates and expectations. The speculation comes from the reasoning above that changes in interest rates affect house prices through multiple channels. As confirmed by numerous empirical findings, the effects of the interest rate channel have proven to be far more influential than previously thought since interest rates affect risk preference, bank-lending and expectation as illustrated in Figure 2.4. Moreover, as illustrated in the same figure, expectations during the boom period amplify the volatility of house prices since most market participants follow the naive type of expectations with the *reaction factor* in the equation (2.12) greater than unity. This reasoning leads to a different regression strategy from these of existing empirical studies in order to answer the question as to what are the main drivers of the *volatile components of house prices* instead of *house prices themselves*.

**Figure 2.3. Income and House Prices in U.S.**



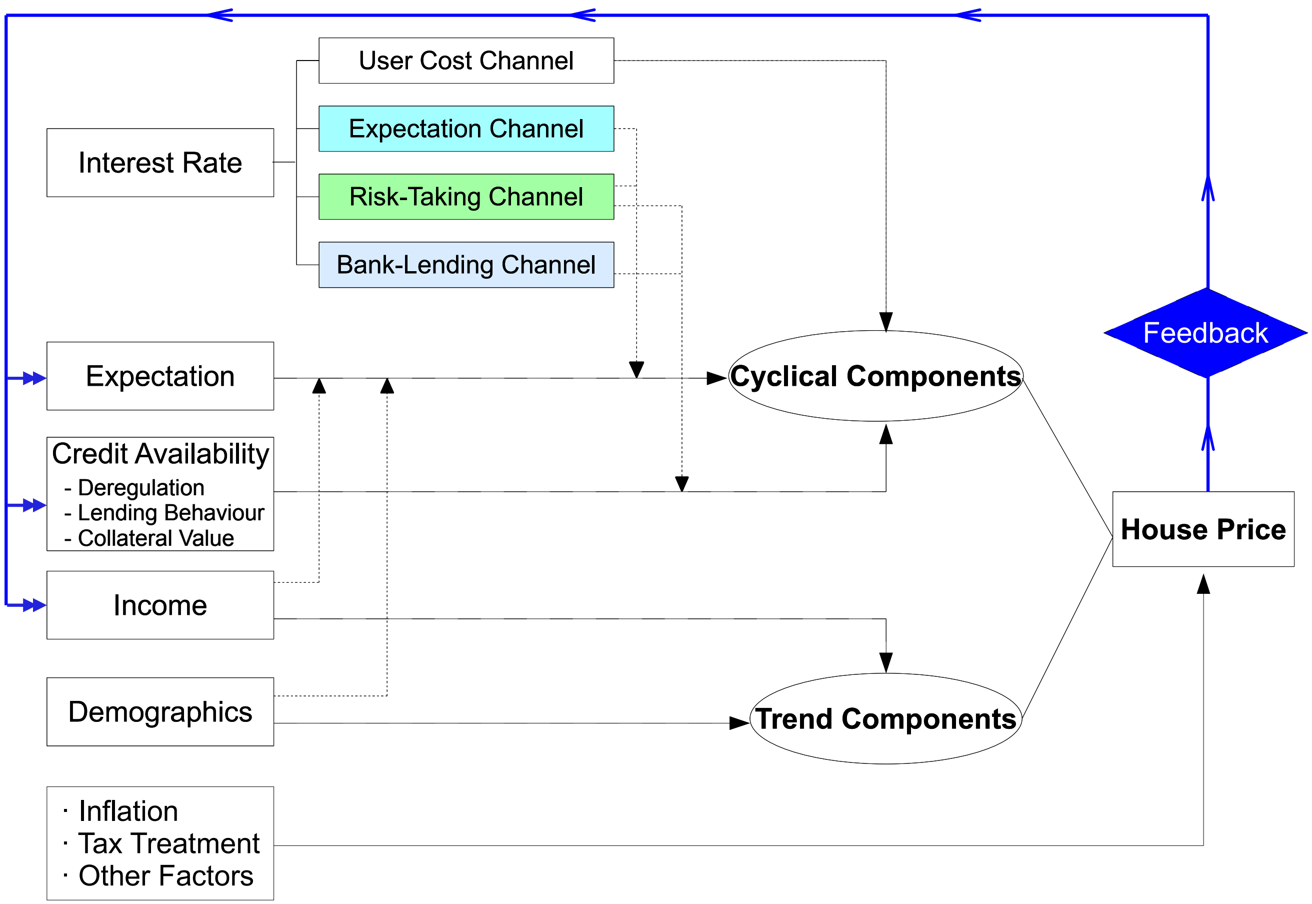

Data Source: Bureau of Economic Analysis, Standard and Poor's Case & Shiller Index

## 2.3 Empirical Analysis of Housing Cycle Drivers

### 2.3.1 Review of Empirical Methods

The most prevalent empirical methods in the existing literature can be classified broadly into three categories: single equation regression, cointegration and its derivative error-correction, and vector autoregression (VAR).

**Figure 2.4. Determinants of Housing Price Cycle**




Notes:

1. The type of line represents the different character of effect of the determinants on house prices.
   - Dotted line: Indirect effect through other determinants
   - Continuous line: Direct effect
   - Blue & Thick continuous line: Feedback effect from house prices to the determinants

2. The expected value of future house prices is defined as the function of past house prices and other determinants.

$$E_t(HP_{t+1}) = f(r, I, HP_{t-i}, D, \dots) \qquad i = 1, 2, 3, \dots$$

where $E_t$ is expectation operator, and $r$, $I$, $HP$, $D$ are interest rate, income, house price, demographics respectively.

#### 2.3.1.1 Single Equation Regression

The simplest form of the single regression equation approach can be abstracted from diverse instances as the following equation.

$$\Delta HP = f(\mathbb{X}) \tag{2.14}$$

where $\mathbb{X}$ denotes a vector of the candidate determinants of housing prices which were discussed in the previous section. In the equation (2.14), $HP$ is the logarithm of the original level data on house prices and hence $\Delta HP$ approximately equals the growth rate over a certain period. The reason for taking the first-order difference of the log time series is mainly for preventing spurious regression results by securing the stationarity of the dependent variable since the level data on house prices in general have proven to be non-stationary.[38] An example of this approach can be found in Englund and Ioannides (1997).

$$HP_t^g = \alpha + \beta_1 \, GDP_t^g + \beta_2 \, r_t + HP_{t-1}^g \tag{2.15}$$

where $HP_t^g$ and $GDP_t^g$ denote the growth rate of house prices and GDP at time $t$ respectively, $r_t$ is the real interest rate and $HP_{t-1}^g$ refers to one period lagged dependent variable. Almeida *et al* (2006) also uses this approach.

The variant form of this approach includes an error correction term as an explanatory variable as follows.

$$\Delta HP = \alpha + \beta_i \mathbb{X} + \gamma(HP - HP^*) \qquad i = 1, 2, \cdots, n \tag{2.16}$$

where $\mathbb{X}$ is again a vector of house price determinants and $HP^*$ refers to the level of estimated

[38] There are two conspicuous exceptions to the case. In the regression equations of DiPasquale and Wheaton (1994) and Muellbauer and Murphy (1997), the dependent variable takes level data and the models pass the Durbin-Watson test successfully. However, the success arises from the inclusion of almost all the candidates, far too many, determinants as explanatory variables in the model which ends in an extremely high level of the coefficient of determination ($R^2$).

equilibrium house price. In the above equation, house price changes are accounted for not only by usual candidate determinants but also by the deviation of the actual level of house price from the fundamental level estimated by using a separate estimation equation. Obviously, the assumption that house prices tend to revert to their equilibrium level makes it plausible to include the error correction term. Abraham and Hendershott (1996) employ the idea by the following equation. Their baseline model is

$$HP_t^g = (HP_t^g)^* + \epsilon_t \tag{2.17}$$

In this equation, the term $\epsilon_t$ represents the linear combination of lagged growth rate and the difference between the actual and equilibrium level of house price.

$$\epsilon_t = \beta_0 + \beta_1 \, HP_{t-1}^g + \beta_2 \, (HP_{t-1}^* - HP_{t-1}) + \nu_t \tag{2.18}$$

where $\nu_t$ is a random error. The error term, $\epsilon_t$ in the equation (2.18) includes an error correction term of $\beta_2 \, (HP_{t-1}^* - HP_{t-1})$.[39] The growth rate of equilibrium real house prices, $HP^*$, is estimated using the following equation.

$$(HP_t^g)^* = \Gamma \mathbb{X} \tag{2.19}$$

where $\Gamma$ is a vector of coefficients and $\mathbb{X} = [1, e_t, y_t, r_t]$ where $e_t$, $y_t$ and $r_t$ mean employment rate, equilibrium income and real after-tax interest rate in sequence. Malpezzi (1999) and Capozza *et al* (2004) follow a similar type of equation even though the dependent variable is price-to-income ratio in Malpezzi (1999) and the explanatory variables are different from these of the model above.

[39] This type of error correction term should be differentiated from the commonly called the *equilibrium error* derived from the cointegrated relationship identified between the level data series of the variables in interest.

#### 2.3.1.2 Cointegration and Error Correction

The second prevalent empirical approach is the cointegration method developed by Engle and Granger (1987) to identify a *long-run equilibrium relationship* between house prices and other relevant economic variables. In this approach, the error correction model derived from the equilibrium relationship is used for clarifying the short-term dynamics of house price changes. A clear advantage of using the cointegrated relationship lies in the fact that it preserves the information contained in the original level data and hence helps to identify a stable long-term relationship among interrelated variables, provided one exists. This method became predominant in the field of housing research, especially after mid-1990s, since it enabled researchers to compare their empirical findings with theoretical models which exploit the concept of level rather than change rates of housing prices. Furthermore, the error-correction model was useful for capturing the dynamic movements of house prices toward the equilibrium level over the short-term horizon. Drake (1993) applied the cointegration method for the first time to estimate a long-term relationship between the house prices in the U.K. and its determinants. Afterwards, the method has been popularly employed in analyzing the housing market of a single country. Examples include Ashworth and Parker (1997), Hollar (2003), IMF (2005), Honjo *et al* (2005, Ch 2.) for the U.K., Hort (1998) for Sweden, Hin and Cuervo (1998) for Singapore, OECD (2004) and Hofman *et al* (2005) for Netherlands, Oikarinen (2005) for Finland, Annett (2005) for 8 European countries. The testing procedure has also been extended to panel data analysis to diagnose the cointegrated relationship among the variables using pooled data. Kasparova and White (2001) and Adams and Fuss (2010) use this panel cointegration method.

A typical example of the cointegration method applied to the housing context can be found in Hollar (2003) which specifies a long-term relationship between house prices and housing demand determinants as below.

$$HP_t = \alpha - \beta_1 r_t + \beta_2 y_t + \varepsilon_t \tag{2.20}$$

where $HP_t$ is the log level of house price at time $t$, $r_t$ is the real interest rate and $y_t$ is real income per household. The consequent error-correction model is defined as follows.

$$\Delta HP_t = \Phi \sum_{i=1}^{3} \mathbb{X}_{t-i} + \gamma \varepsilon_{t-1} + \upsilon_t \tag{2.21}$$

where $\Phi = (\phi_1, \phi_2, \phi_3)$ in which each element represents the coefficients of the column vector $\mathbb{X} = (HP, r, y)'$ at the time period of $t - i$. Despite its manifest benefits, the common limitation of all the econometric methods is also true of this method. As Enders (2004, pp. 322) notes correctly, the equilibrium relationship in econometrics refers to any long-run relationship among nonstationary variables and it can be simply a behavioural reduced-form relationship among similarly trending variables. Therefore, without a solid theoretical foundation, any implication obtained from a cointegrated relationship can be specious and hence lead to misjudging the relationship between house prices and other economic variables. From this perspective, a theoretical framework for defining the equilibrium of the housing market is necessary for imbuing a simply statistically significant relationship with an economic implication. There are several examples employing cointegration equations based on theoretical considerations of the equilibrium in the housing market. Hollar (2003) and Annett (2005) implicitly impose the *demand-only framework* while Kasparova and White (2001) and Adams and Fuss (2010) lay down the *supply-demand equilibrium framework* for setting up regression models for cointegration.

#### 2.3.1.3 Vector Autoregression

The most recent approach to identify the relationship between house prices and other economic variables is VAR pioneered by Sims (1980) in which all the related variables are regarded as endogenous. The original motivation of VAR analysis is for taking into account interactions between correlated economic variables and to prevent possible misspecification problems resulting from improper restrictions on equations of the variables. For example, in the two approaches of regression and cointegration, all the independent variables in the regression equations are assumed to be exogenous to house prices while in a VAR model the variables are presumed to interact in a multilateral direction. The rationale for the presumption is, for example, the observation that the changes in house prices can affect other economic variables, such as income, by influencing the level of consumption and construction investments.

VAR has become a prevalent analysis tool in the research on housing after the reverse direction of the influences running from housing prices toward the overall economy was perceived as crucial for forecasting future economic circumstances. The evident advantage of VAR over the preceding methodologies is that the feedback loop operating between the variables of interest can be revealed by impulse response function. Its additional practical advantage is that it can be implemented without painstaking investigation into a causal chain or a theoretical mechanism. The related literature includes Iacoviello (2000), Sutton (2002), Tsatsaronis and Zhu (2004), Goodhart and Hofmann (2008) and Jarocinski and Smets (2008).[40]

Despite the advantages mentioned above, the VAR approach to housing market dynamism has a couple of limitations setting aside the general problems such as the instability of a system caused by fixed parameters and the indeterminacy of coefficient values as pointed out by Stock and Watson (1996) and Robertson and Tallman (1999). Above all, no criterion for selecting endogenous variables has been established in employing VAR. A firm basis for judging which variables should be included in and excluded from a vector is crucial since inclusion and omission of a certain variable can alter substantially the magnitude of the coefficients of other variables. To provide convincing results through employing VAR, it is indispensable to closely examine the level of endogeneity and correlation before selecting variables.

The second limitation of the VAR approach is that it is inherently not appropriate for illuminating causality running from a variable to house prices especially because of the assumption on endogenous relationships among all the variables included in a vector. The

[40] The specific form of VAR varies among the literature. The first three papers use Structural VAR (SVAR) which imposes a restriction on the order of endogenous variables based on the judgement of the directions of influence among the variables. The fourth uses a panel VAR as they pool the data from 17 industrialized countries and the last one uses Bayesian approach (BVAR) to identify the distribution of the coefficients in the model.

assumed endogeneity among the variables is as strong a restriction as one imposed on the simultaneous equation system which had been a prevalent econometric technique before VAR was developed. Once the assumption of endogeneity is imposed, the causality is hard to identify through the impulse response function because it describes interrelations rather than causality. In that sense, what VAR presents fundamentally is not an anatomy of a relationship in question, but simply a description of a superficial outlook on the relationship. Furthermore, as in the cointegration method, the description of the interrelationship can be spurious. For instance, the empirical results found by Tsatsaronis and Zhu (2004) deviate from the findings of past literature in that inflation explains the largest portion of house price variations whereas income exerts a minimal influence.[41] Acknowledging that inflation can change the demand for housing and hence house prices, it can hardly be acceptable without theoretical expositions that inflation assumes the most prominent role in determining house prices. Considering these limitations, VAR should be used for the purpose of verifying the validity of theoretical formulations rather than for eliciting a novel relationship.

To summarize the considerations about the three empirical tools used in the literature, each individual method contains its own relative advantages and disadvantages. As a result, there is no concluding which method is superior to the other ones. For example, if short-term dynamics receive more interest, the cointegration method is a more appropriate tool while VAR is superior to other econometric methods in capturing the interrelationships among a set of variables. As can be noticed from the literature introduced above, all three methods are still being employed by researchers and the results produced by one method vie with these produced by the other ones.

[41] In the model, the vector includes 6 endogenous variables: the growth rate of GDP, the rate of inflation, the real short-term interest rate, the term spread between the yield of a long-term government bond and short-term interest rate, bank credit, and the growth rate of house prices. The data comes from 17 industrialized economies from 1970 to 2003.

## 2.4 Alternative Approach to Housing Cycle by Decomposition Method

Most of the empirical studies on the relationship between house prices and their determinants have focused to date on explaining the overall house price fluctuations using the methods described in the previous subsection. Only recently, Agnello and Schuknecht (2011) have adopted a different strategy to identify the determinants of the booms and busts of the housing market using a Probit model in which the probabilities of these events are the main variable of interest. However, the empirical results still fall short of providing a definitive answer to the question of what drives the regularly cyclical behavior of house prices. To answer the question, a novel regression strategy is employed in this chapter which consists of two stages. At the first stage, observed house prices are decomposed into stably changing trend components and volatile cyclical components. At the second stage, the degree of deviation, measured by the absolute value of the ratio of the cyclical component to the trend component at each time period, is regressed on the candidate determinants of housing prices which were studied in the previous section. The rationale for adopting this strategy is firmly based on the reasoning that the volatility observed in the time series of house prices appears to be associated more with interest rates and expectations than with trend-stationary variables such as income. A hypothesis to be tested by the regression analysis derives from the reasoning that the variations in the cyclical components of house prices can be explained mainly by changes in interest rates and expectations rather than other housing price determinants. It is equivalent to assuming that house prices would be on the path of a certain stable long-term upward trend without interest rate changes and expectational effects.

### 2.4.1 Practical Issues

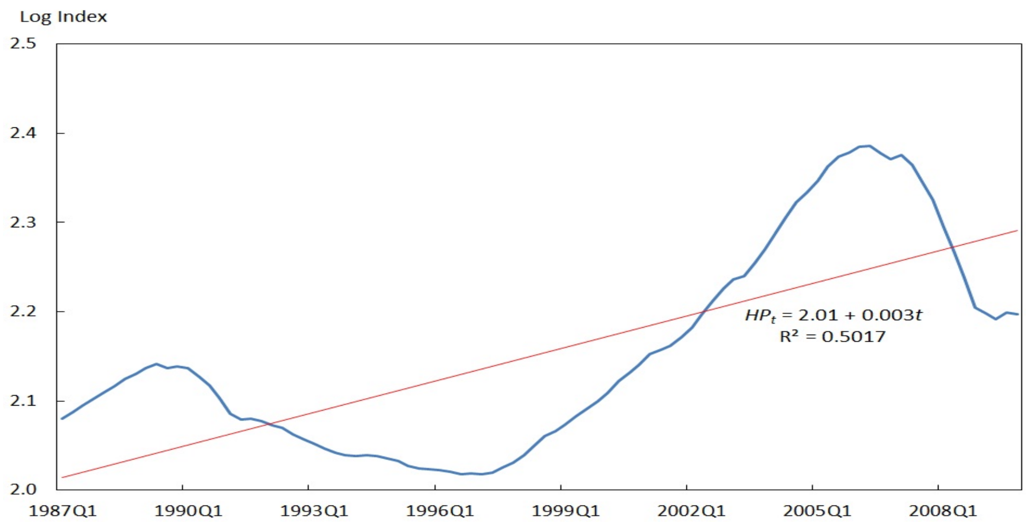
Two practical issues should be resolved to implement this strategy: choice of a proper decomposition method and selection of a specific level of the parameter of the method. As regards the first issue, the Hodrick-Prescott filter (HP filter) is preferred in that the filter has been popularly used not only by business cycle researchers to extract cyclical components from the various macroeconomic variables but also by researchers in different fields, mainly the ECB economists, to identify the boom and bust periods of asset or housing markets (Bordo and Jeanne, 2002; Detken and Smets, 2004; Adalid and Detken 2007; Goodhart and Hofmann, 2008; Alessi and Detken, 2009; Agnello and Schuknecht, 2011).[42] However, it is still questionable whether application of the HP filter to the time series of housing prices is appropriate since the filtering method was originally devised for the time series containing long-term growth components. Apparently, extending the HP filter coverage beyond the boundary of the business cycle context seems to have been initiated by Gourinchas *et al* (2001) in which the trend of credit-to-GDP ratio is estimated by the HP filter. The application of the HP filter in the context of asset markets is based on the same assumption that "aggregate economic variables in capitalist economies experience repeated fluctuations about their long-term growth paths" as stated in Hodrick and Prescott (1981). In light of this, before applying the filter to the time series of house prices, the question should be tackled whether the time series shows a persistent growth path similar to that of consumption and investment. The data on housing prices of the Case & Shiller Index in the U.S. is set out in Figure 2.5. The upward linear time trend in the figure implies that certain forces have propelled the time series upward for the last two decades. Based on the graph appearing in Figure 2.5, applying the filter to house prices is compatible with the presumption of Hodrick and Prescott (1981).[43]

The second issue in operating the filter involves selecting the level of the smoothing parameter which determines the smoothness of the growth component series obtained by solving

[42] Moving average is another popular method to extract trend components. Borio and Lowe (2002) implicitly use average growth rate plus its certain level of standard deviation as the trend.

[43] It is questionable whether continuing upward trend also can be discerned if the time horizon of house prices extend further back into the past. For the U.S. case, Shiller (2005) argues long-run upward trend appears not to exist by presenting the longer series of house price index during the period from 1980 to 2004 constructed by combining 5 source indexes (pp.12-25). However, another query can be raised about effectiveness of the constructed index since the range of samples and compilation methods vary depending on the source index.

**Figure 2.5. Linear Time Trend of House Prices in U.S.**




Data Source: Standard and Poor's Case & Shiller Index

the following problem.

$$\min_{\{g_t\}_{t=-1}^{T}} \left\{ \sum_{t=1}^{T} {c_t}^2 + \lambda \sum_{t=1}^{T} [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \right\} \tag{2.22}$$

under the assumption that

$$y_t = g_t + c_t \qquad\qquad t = 1, \cdots, T \tag{2.23}$$

where $y_t$ denotes a given time series, $g_t$ are growth components and $c_t$ are cyclical components which measure the deviation of the time series from $g_t$. If the parameter $\lambda$ in the equation (2.23) approaches infinity, the solution for the minimization problem is simply a linear time trend. With $\lambda$=0, the solution is simply the given original time series.[44] Hodrick and Prescott (1981) select $\lambda$=1,600 based on their prior belief about the moderate level of volatility of the growth and cyclical components. In order for the estimated growth component $g_t$ to be a solution to the minimization problem under a set of assumptions, $\sqrt{\lambda}$ is required to equal $\sigma_1/\sigma_2$

[44] Dejong and Dave (2007) interpret the parameter $\lambda$ as a weight or value given to the smoothness of the growth components (pp. 37). For example, the case of $\lambda$=0 means that smoothness receives no weight.

where the numerator and denominator denote the standard error of cyclical components and the second differences of the growth components respectively. The prior of the two standard errors are 5 for $\sigma_1$ and 1/8 for $\sigma_2$. These values lead to the ratio of 40.[45]

Thereafter the value 1,600 for the smoothing parameter has been accepted as the standard level for quarterly business cycle data, 100 for annual data and 14,400 for monthly data (Favero, 2001; pp.54). In stark contrast with the careful considerations on the choice of $\lambda$ in the business cycle literature, any rationale for selecting a certain level of the parameter is not explicitly provided in the empirical studies on assets and housing markets listed above. For annual data, Detken and Smets (2004) choose 1,000 for annual data simply following the lead of Gourinchas *et al* (2001) which again lacks explanation about the reason for choosing that level. On the other hand, Agnello and Schuknecht (2011) select 10,000 for annual data. In all the other remaining papers in the above list of ECB papers, the parameter value is set as 100,000 for quarterly data which by far exceeds the level widely used in the research on business cycle.

Focusing only on the frequency of the data, it is plausible to set the level of $\lambda$ as 1,600 since the quarterly data will be used in the regression analysis below as in the business cycle research. However, considering the different property of house price data from macroeconomic aggregate variables, three values of the parameter, 1,600, 10,000 and 100,000 are tried preliminarily. Judging from the regression results, the level of 1,600 turns out to be the most appropriate one for eliciting a meaningful relationship between the deviation of house prices from their trend and the candidate determinants.

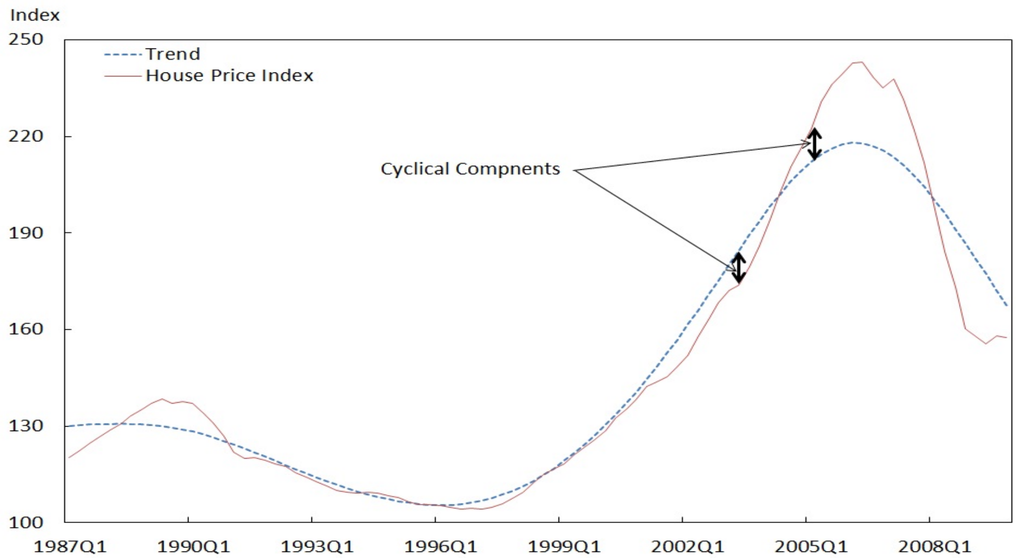
### 2.4.2 Results of Empirical Analysis

The first step to take for the regression is to extract cyclical components from the time series of U.S. real house prices. The next step is to measure the degree of deviation of actual house

[45] Canova (2007) provides more detailed consideration about the choice of $\lambda$ (pp. 83-84) and DeJong and Dave (2007) explain the underlying logic for the value by frequency domain analysis (*Ibid*; pp. 38-46).

prices from the estimated trend by dividing the absolute value of the cyclical components by the level of the trend components. Figure 2.6 illustrates the extracted trend from the S&P/Case-Shiller(CS) 10-city composite index realized by the CPI index less shelter from 1987 Q1 to 2009 Q4.

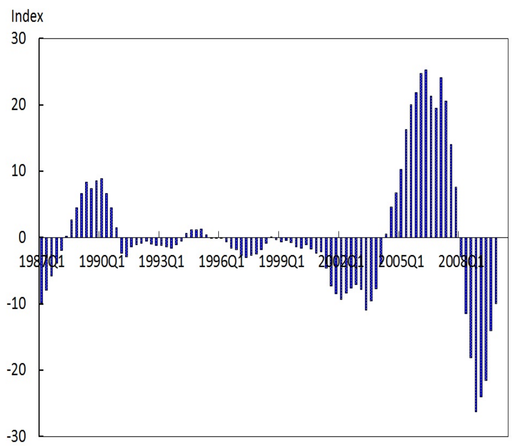
**Figure 2.6. Filtered Trend of House Prices in U.S.**

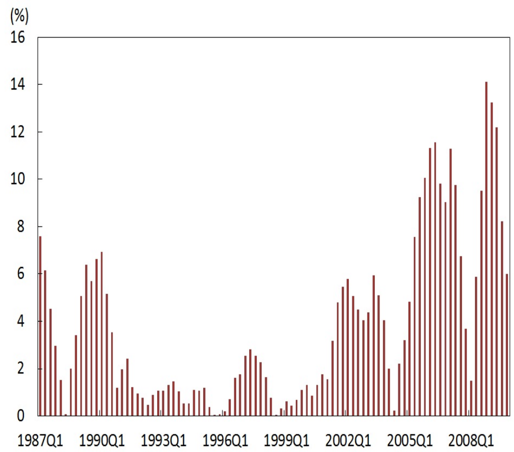



The vertical distance between the two lines denotes the cyclical components which are graphed in the left panel of Figure 2.7. The original values of the components are expressed in absolute terms as illustrated on the right panel in the same figure and divided by the values of the estimated trend components. Put in notations, $DEV_t = |C_t/T_t| \times 100$ where $C_t$ and $T_t$ denote the estimated cyclical components and trend components respectively. As such, $DEV_t$ gauges the degree of deviation of the observed house prices from their estimated trend.

In the next stage, the degree of deviation $DEV_t$ is regressed on the determinants of housing prices which are represented by the following seven explanatory variables with one period lag: interest rates ($i_{t-1}$), lagged dependent variable ($DEV_{t-1}$), the rate of change in house prices ($HP^g_{t-1}$) and income ($INC_{t-1}$), the rate of change in real estate loan ($CRD_{t-1}$) and inflation ($INF_{t-1}$), and demographic change ($D_{t-1}$) representing the rate of change in the number of households. These variables take the absolute value of the original data and hence

**Figure 2.7. Cyclical Components of House Prices and Deviation from Trend**




the coefficient of each change rate is interpreted as the influence of one unit change in the independent variables on the degree of house price deviation from the estimated trend. The simplified form of the regression equation is as follows.

$$DEV_t = \alpha + \Psi \mathbb{X}'_{t-1} + \epsilon_t \qquad\qquad t = 1, \cdots, T \tag{2.24}$$

where $\mathbb{X}'_{t-1}$ refers to the row vector of the explanatory variables and $\Psi$ is the vector of the corresponding coefficients. Among the variables, both $DEV_{t-1}$ and $HP^g_{t-1}$ are introduced into the regression model to represent expectational effects, and $CRD_{t-1}$ measures credit availability. It is necessary to give further explanation about the reason for these representations. Firstly, expectation of the future degree of deviation is assumed to take the modified naive form of expectations to reflect the strong inertia latent in house prices. The modification lies in that the information utilized for forming expectations include not only the level of the deviation degree but also the growth rate of house prices in the previous period. Agents are assumed to form their expectations based on the deviations in the previous period and house price changes. The following equation illustrates this specific form of expectations.

$$E_{t-1}\, DEV_t = \varphi\, DEV_{t-1} + \psi\, HP^g_{t-1} \tag{2.25}$$

where $E_{t-1}$ denotes expectation operator at the time $t-1$.[46]

Secondly, regarding credit availability, there seems to be no proper measure since the variable is hard to quantify in practice. In the absence of any correct metric for the variable, using the conventional measure of credit such as consumer credit or real estate loans can be a plausible proxy. Substituting this equation into the equation (2.24) and extending it yields the regression equation below.[47]

$$\begin{aligned} DEV_t =& \alpha + \beta_1 i_{t-1} + \varphi DEV_{t-1} + \psi HP^g_{t-1} + \beta_2 INC_{t-1} \\ &+ \beta_3 CRD_{t-1} + \beta_4 INF_{t-1} + \beta_5 D_{t-1} + \epsilon_t \qquad t = 1, \cdots, T \end{aligned} \tag{2.26}$$

Table 2.2 presents the results of the regression using the S&P/Case-Shiller 10-city index as the source data for the dependent variable. The sources and properties of the data for the other variables are described in detail in Appendix A. The regression models (1) and (2) in that table include the same set of independent variables except for interest rates $i_{t-1}$. The interest rate is short-term in the former model whereas it is long-term in the latter one. The purpose of using a different type of interest rates in these two models lies in comparing the explanatory power of each type of interest rates. The results of models (1) and (2) are both consistent with the hypothesis that the factors except for interest rates and expectations turn out to exert an insignificant influence on the volatile components of house prices. To find a model better fitting the data, these insignificant variables are removed and further regressions are conducted on the remaining variables. In model (3), the sign of the long-term interest rate is negative, which runs contrary to the prediction that interest rates amplify the volatility of house prices rather than dampen them. Furthermore, the coefficient proves to be insignificant even at the 10% significance level. Compared to model (3), the coefficients of the short-term interest rate and other explanatory variables in model (4) show positive signs as expected and

[46] This equation is specified by employing the naive type of expectation in which economic agents consult only the information of the current period.

[47] The specification of the regression equation is based on the preliminary regressions results obtained by using the general-to-specific approach in which only one-period lagged variables appear to be relevant.

**Table 2.2. Determinants of House Price Deviation from Trend**

House price data source : S&P/Case-Shiller House Price Index(1987.Q1 - 2009. Q4)

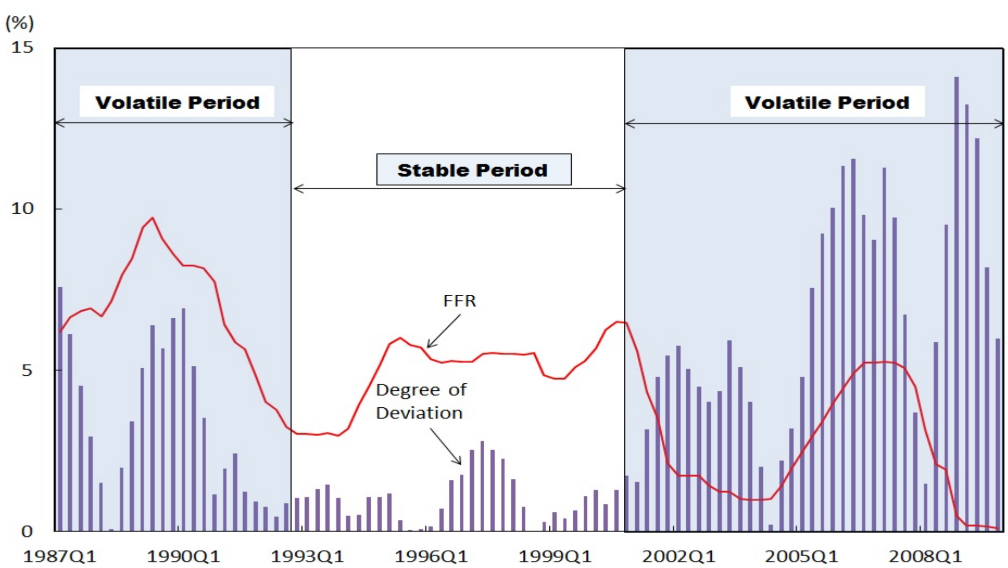
| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dependent variable($DEV_t$): $DEV_t = \lvert C_t/T_t \rvert \times 100$ | | | | |
| Constant | -1.397 | -1.672 | -0.552 | -0.848 |
| | (-1.795) | (-2.482) | (-1.443) | (-2.826) |
| Nominal interest rates ($i_{t-1}$) | | | | |
| Long-term | 0.317 | | -0.104 | |
| | (0.315) | | (-0.112) | |
| Short-term | | 1.335 *** | | 1.301 *** |
| | | (3.462) | | (3.390) |
| Lagged dependent variable($DEV_{t-1}$) | 0.848 *** | 0.852 *** | 0.859 *** | 0.862 *** |
| | (18.733) | (20.449) | (20.137) | (21.614) |
| House price change($HP^g_{t-1}$) | 0.116 *** | 0.093 *** | 0.105 *** | 0.080 *** |
| | (3.339) | (2.812) | (3.647) | (2.874) |
| Income change($INC_{t-1}$) | 0.523 ** | 0.520 ** | 0.444 * | 0.448 * |
| | (2.000) | (2.172) | (1.761) | (1.914) |
| Real estate loan($CRD_{t-1}$) | 0.046 | 0.049 | | |
| | (1.268) | (1.463) | | |
| Inflation ($INF_{t-1}$) | 0.043 | 0.045 | | |
| | (0.754) | (0.391) | | |
| Demographic change ($D_{t-1}$) | -0.091 | -0.183 | | |
| | (-0.140) | (-0.307) | | |
| *Adj.* $R^2$ | 0.861 | 0.889 | 0.863 | 0.880 |
| *DW* | 1.721 | 1.972 | 1.815 | 1.931 |
| *AIC* | 3.502 | 3.362 | 3.457 | 3.326 |

Note: The asterisks *, **, *** indicate significance at 10%, 5%, 1% level respectively and t-statistic appears in the parentheses. *DW* and *AIC* represent Durbin-Watson statistic and Akaike information criteria respectively.

are statistically significant.

Based on model (4), the degree of deviation fluctuates mainly due to the changes in the short-term interest rates and the expectations which are assumed to be a linear combination of one-quarter lagged degree of deviation ($DEV_{t-1}$) and the house price change rate ($HP^g_{t-1}$) as in the equation (2.25). To interpret the coefficients, an increase of 1%p in the short-term interest rates heightens the degree of deviation by 1.30%p further from the estimated trend. Turning to the expectational effects, the total magnitude of the coefficient is 0.94 which is slightly below that of interest rates. The reason why interest rates generate stronger volatility needs a separate investigation, but a possible conjecture is that interest rates exercise their influence throughout the whole time period whereas the modified form of expectations specified above plays a more critical role in the extreme phases such as the pronounced housing boom and bust periods. In contrast, the influence of income is relatively limited compared with these of interest rates and expectations as the degree of deviation increases by 0.45%p in reaction to a 1% change of income level. All of these results lend support to the hypothesis that the trend path of housing prices is driven mainly by the variables changing slowly and smoothly while the cyclical components are generated by changes in interest rates and expectations. Figure 2.8 shows that this prediction is consistent with the actual paths of the federal funds rate (FFR) and the degree of deviation.

**Figure 2.8. Short-term Interest Rates and Degree of Deviation**




The limitation of the results from model (1) in Table 2.2 is that the error term $\epsilon_t$ is likely to be serially correlated considering the low level of Durbin-Watson ($DW$) statistics.[48] The problem may arise from the asymmetric coverage of the data used for the dependent variable

[48] Considering the high level of t-statistic for interest rates and expectation, the test results may not differ even though the standard errors of the coefficients are measured correctly.

and explanatory variables.[49] The data for calculating the dependent variable $DEV_t$ is the S&P/Case-Shiller 10-City Composite Index which covers the major cities in the U.S. while the data for all the other explanatory variables are nationwide.[50] To check whether widening the coverage of the dependent variable can improve the robustness of the regression results in Table 2.2, the 10-City Index is replaced by the national house price index (NHPI) published by the FHFA (Federal Housing Finance Agency) to calculate the degree of deviation.[51] Even though it is not appropriate to elaborate on the detailed differences in the calculation methods of these two indices, it is worth mentioning the relative advantages. The advantage of the 10-city index lies in its allowing for quality change by employing the sophisticated weighting methodology, while the disadvantage is that the index has a relatively short history starting from 1987. In contrast, the national house price index (NHPI) has a longer time series starting from 1975 and covers more transactions, but it lacks consideration of quality variation occurring to the samples at different time points.

Among the regression results obtained using NHPI data in Table 2.3, model $(3)'$ delivers the most consistent result with that of model (4) in Table 2.2 having a higher level of $DW$ statistic. Firstly, as can be recognized in model $(1)'$ and $(2)'$, inflation and demographic changes have no explanatory power for the extent of house price deviation from the trend. Secondly, interest rates exercise the strongest influence on the degree of deviation. There also exist several conspicuous differences between the two sets of regression results. Firstly, the type of interest rate which proves to be relevant is not short-term but long-term in the new regression. Secondly, income changes prove to be insignificant and changes in real estate loans is significant even though their influence appears to be trivial. However, notwithstanding these differences, the regression results of the models using different house price indexes

[49] There are alternative ways to overcome a serial correlation problem, such as White or Newey-West testing techniques. However, as the asymmetric coverage of the data appears to be a more influential reason for the problem, it is probable that using the house price data covering the whole nation is an appropriate solution.

[50] The list of 10 cities includes Boston, Chicago, Denver, Las Vegas, Los Angeles, Miami, New York, San Diego, San Francisco and Washington D.C.

[51] Before the FHFA was founded in 2008 combining the former Office of Federal Housing Enterprise Oversight (OFHEO), the Federal Housing Finance Board (FHFB), and the GSE mission office at the Department of Housing and Urban Development (HUD), the NHPI was published by OFHEO.

are not fundamentally incompatible. For example, the income change in regression model (4) is significant only at the 10% level similar to the case of model $(2)'$. In addition, the influence of changes in real estate loans in model $(3)'$ is negligible as in model (1). Thus, if we ignore the slightly different implications, the regression results produced using the different data on housing prices reconfirm the hypothesis about the dominant role of interest rates and expectations in driving the cyclical components of housing prices fluctuating about the trend.[52]

It is difficult to compare these results presented above with those in existing literature previewed in the earlier sections since the dependent variable used for the regression analysis has not been analysed in the past empirical studies. Nevertheless, the most remarkable difference is that income changes are insignificant in the regression results above whereas they are among the most noticeable determinants of housing prices. However, this difference arises possibly because the explanatory power of income change is confined to the trend components extracted from house prices. In light of that, comparison of the above results with the findings in Agnello and Schuknecht (2011), which are referred to in the previous section, is more pertinent because the fundamental motivation underlying each analysis is similar. They regressed the probability of the boom and bust events on the common determinants of house prices using the sample data of 18 countries from 1980 to 2007. In their finding, changes in real GDP per capita turn out to have the most potent power for determining the probability of housing boom and bust occurrences. To point out a couple of limitations of the results, the expectational factor is not considered explicitly even though the extraordinary boom phases of the housing market are more likely to be driven by excessively optimistic expectation. As a result, the omission of expectations may over-estimate the influence of GDP. An additional limitation is that GDP can be a poor proxy for the ability to able to buy a house since it includes various types of taxes and capital depreciation.

[52] There is a possible limitation of these regression results: the dependent variable $DEV$ and the growth rate of house prices$HP^g$ are highly persistent and hence the one-period lagged terms of these variables may not be able to correctly capture the effects of expectation.

**Table 2.3. Determinants of House Price Deviation from Trend**

House price data source : National House Price Index(1987.Q1 - 2009. Q4)

| | $(1)'$ | $(2)'$ | $(3)'$ | $(4)'$ |
|---|---|---|---|---|
| Dependent variable($DEV_t$): $DEV_t = \|C_t/T_t\| \times 100$ | | | | |
| Constant | -0.421 | 0.261 | -0.598 *** | -0.227 |
| | (-0.893) | (0.541) | (-1.996) | (-0.806) |
| Nominal interest rates ($i_{t-1}$) | | | | |
| Long-term | 2.105 *** | | 2.122 *** | |
| | (3.359) | | (3.460) | |
| Short-term | | 0.013 | | 0.545 *** |
| | | (0.043) | | (1.912) |
| Lagged dependent variable($DEV_{t-1}$) | 0.693 *** | 0.688 *** | 0.694 *** | 0.685 *** |
| | (8.076) | (7.495) | (8.248) | (7.784) |
| House price change($HP^g_{t-1}$) | 0.187 | 0.169 | 0.205 * | 0.178 |
| | (1.514) | (1.283) | (1.777) | (1.467) |
| Income change($INC_{t-1}$) | 0.031 | 0.010 | | |
| | (0.382) | (0.119) | | |
| Real estate loan($CRD_{t-1}$) | 0.042 * | 0.029 | 0.047 ** | 0.040 ** |
| | (1.781) | (1.174) | (2.089) | (1.696) |
| Inflation ($INF_{t-1}$) | -0.025 | -0.034 | | |
| | (-0.751) | (-0.952) | | |
| Demographic change ($D_{t-1}$) | -0.093 | -0.002 | | |
| | (-0.213) | (-0.005) | | |
| *Adj.* $R^2$ | 0.597 | 0.578 | 0.608 | 0.591 |
| *DW* | 2.202 | 2.137 | 2.306 | 2.278 |
| *AIC* | 2.764 | 2.891 | 2.707 | 2.795 |

Note: The asterisks *, **, *** indicate significance at 10%, 5%, 1% level respectively and t-statistic appears in the parentheses. *DW* and *AIC* represent Durbin-Watson statistic and Akaike information criteria respectively.

## 2.5 Conclusion

Our analysis supports the conclusion that house prices in the U.S. from 1987 to 2009 have been driven mainly by interest rates and expectations. These results support the dominant role of *short-term* interest rates in the housing market: something which has been taken for granted in the debate on the sources of the sub-prime crisis. Nevertheless the results fall short of confirming the accountability of monetary policy decisions for the volatile evolution of house prices in the U.S. since the majority of mortgage contracts are linked to *long-term* interest rates. However, it can be inferred from the stable term structure between short-term and long-term interest rates that the decreases in policy rates are also fundamentally responsible for fostering the abnormalities in the housing market.

An additional implication from the results is that expectations have not been given enough attention as a prime driver of the housing cycle. Further research is necessary for understanding the actual behaviour of public's expectations and its influence on house price fluctuations. Two apparent limitations of the empirical results presented above are worth mentioning. The first one is related to the presumption that the path of the extracted *trend components* depends more on income change and demographics. Despite its plausibility, this should be verified more rigorously since this is the main rationale for the regression strategy. The second problem, which is common to other empirical studies, is the possibility that the proxy variables may misrepresent the original ones. The modified form of expectation calculated by the linear combination of the lagged dependent variable and house price change may cause measurement errors since the behavioural form of expectations varies depending on the specific situation of the housing market as elaborated before.

# Chapter 3

# Monetary Policy Transmission via Risk-taking Channel in Mortgage Markets

## 3.1 Introduction

It has been maintained that the deregulation and liberalization of housing finance since the 1980s have broadened credit availability which in turn has led to more pronounced fluctuations in housing prices. Specifically, banks and governmental mortgage agencies were allowed under the liberalization process to produce a wide range of mortgage loan products, set lending interest rates at their own discretion, determine the level of loan-to-value (LTV) ratio based on their own judgement rather than regulatory prescriptions, and so forth. Moreover, non-bank financial corporations were given permission to enter the mortgage market, thereby heightening the degree of competition in this market.[1] Consequently, easier credit supply to the housing market has increased the volatility of the demand for housing and house

[1] The characteristics of housing finance in each country is distinct. IMF (2008) and Calza *et al* (2009) provide indicators of the differing developments in mortgage financing in industrialized countries. ECB (2009) surveys the recent circumstances of housing finance in the Euro area since 1999.

prices, and in turn amplified further repercussions of the housing sector on consumption and residential investment. These developments in housing finance retain substantial implications for the analysis of monetary policy transmission. Recent findings support the view that the financial liberalization process has rendered the housing sector and the rest of the economy more responsive to a monetary policy shock as interest rates affect credit availability more significantly in a deregulated environment (Iacoviello and Minetti, 2003; IMF, 2008; Calza *et al*, 2009).[2] [3]

The aforementioned findings are obtained under an assumption that mortgage market characteristics are exogenously determined by the financial deregulation process. Recently, a line of research has raised the issue of a possible causal link between an accommodative monetary policy stance and bank lending behaviour. Researchers pursuing this line of reasoning highlight the observed facts regarding lending markets in the run-up to the recent housing boom which numerous developed countries underwent. During that period, lending criteria were loosened appreciably, the minimum down-payment decreased considerably while policy rates were deemed relatively lower than a specific judgement criterion, for example, the Taylor rule or estimated neutral interest rates. The crux of the findings of these researchers is that low interest rates for such a protracted period increased banks' appetite for higher risk in lending and other investments. This transmission channel of monetary policy is labeled the *risk-taking channel* by Borio and Zhu (2008). However, the underlying rationale for the *risk-taking channel* has been highlighted by central bankers. Greenspan (2010), for example, ascribes the failure of the banking system during the recent financial crisis to the possibility that the prolonged period of a relaxed policy stance might have driven banks to neglect the negative tail of investment risk (Greenspan, 2010); this comment implies that the overall per-

[2] Regardless of the recognized importance of credit availability in housing finance, there exist a limited number of findings about the relationship between credit availability and house prices. The reason for this is that there are few trustworthy measures of *credit availability* itself. Even though the amount of mortgage debt seems a plausible proxy for the variable, the amount registered in banks' books is not a proper measure since it is the realized value of *credit availability*. Furthermore, changes in mortgage depend on other factors besides it.

[3] Another relevant finding is in Almeida *et al* (2006) which confirms that the response of house prices to income shocks is more rapid in those countries having a higher ceiling on the LTV ratio

ception of risk was positively biased. Voices from the European Central Bank (ECB) have expressed apprehension from a similar viewpoint; low interest rates for a prolonged period abet moral hazard in banks' investments imbuing them with a myth that the cental bank may not be able to reverse interest rates rapidly because of worries about asset market collapse (ECB, 2005; Trichet, 2005; Papademos, 2006).[4]

These reflections provide a motivation to consider the relationship between low interest rates and banks' risk taking attitude. I submit the hypothesis that a positive monetary policy shock causes banks to raise the LTV ratio and supply ample liquidity to the housing market, thereby rendering the path of house prices and consumption more volatile. In a nutshell, this chapter has two aims: firstly, to verify the existence of the risk-taking channel in the mortgage market, and secondly, to estimate the repercussions of an expansionary monetary policy shock on the economy as a whole via this channel. These aims are attained through a two-stage analysis. To examine the existence of the *risk-taking channel*, namely, a negative relationship between monetary policy rates and the LTV ratio, two kinds of empirical analyses, i.e. regression and VAR, are conducted using U.S. time series data. Although there are various indicators of the degree of banks' risk-taking, the LTV ratio is chosen as an effective one as mortgage lenders tend to set the ratio depending on their own perception of the risk latent in housing-collateralized lending. Subsequently, a DSGE model is developed incorporating an estimated regression equation for the *risk-taking channel* to analyze its role in a broader economy. In the DSGE model, the LTV ratio is defined as a function of policy rates and house price inflation and is set less than unity. This variable plays a key role in amplifying and propagating an initial shock to the economy.[5] In addition, the model follows the lead of Iacoviello (2005) and Iacoviello and Neri (2010). These papers adapted the financial accelerator mechanism of Kiyotaki and Moore (1997) to investigate the dynamics of the housing sector and its spillover into the rest of the economy.

[4] The government's intervention to relieve troubled banks through bailout programs also has been referred to as a cause of the 'too big to fail' myth.

[5] The ceiling on the LTV ratio in practice can exceed one, as in the U.S. which raised the maximum ratio up to 125%. However, only a small portion of borrowers can take advantage of this ceiling as other income requirements and lending criteria should be satisfied.

There are two notable contributions in this chapter which set it apart from the rest of the literature on bank risk-taking and financial friction in lending. Firstly, this analysis is the first attempt, to the best of my knowledge, to delve into the effects of the *risk-taking channel* employing a general equilibrium framework. Secondly, the model in this chapter *endogenizes* the LTV ratio for the first time.

To elaborate on the second point, the LTV ratio in existing models is assumed to be a fixed constant (Monacelli, 2008; Calza *et al*, 2009; Iacoviello and Neri, 2010). An improvement over the constant LTV ratio is the assumption of a time-varying exogenous stochastic process as in Pariés & Notarpietro (2008) and Gerali *et al* (2010), but still this stochastic ratio is not affected by other variables in the model. However, in practice, since banks adjust the LTV ratio on the basis of an evaluation of default risk and the redeemable value of collateral in case of foreclosure, the existing way of treating the LTV ratio in economic models is clearly unsatisfactory. Endogenizing this ratio bases the model more firmly on realistic aspects of housing finance. An additional advantage of introducing the LTV ratio in this manner is the resultant parsimony of the model. As opposed to the models in, for instance, Goodfriend and McCallum (2007), Cúrdia and Woodford (2008), and Gerali *et al* (2010) which introduce a separate block for financial intermediation, the supply side of credit can be reflected in my model by allowing the LTV ratio to vary depending on the banks' decision.

The main findings of the analysis are twofold. First, the results from the regression and VAR analysis lend firm support to the assertion that there is a negative relationship between short-term interest rates and the LTV ratio. It implies mortgage suppliers have tended to be more aggressive in housing-collateralized lending in the period of low interest rates. Secondly, a positive monetary policy shock in the model with the *risk-taking channel* included produces enhanced deviations of consumption and financial debt from the steady state than the model without this channel. These findings can shed light on the conundrum why central bankers, before the sub-prime crisis, failed to forecast the catastrophic results stemming from low interest rates for a prolonged period; presumably they dismissed the *risk-taking channel* when analyzing the transmission effects of their monetary policy decisions. Furthermore, the results justify the need for central banks to pay more attention to the possible existence of more as yet undiscovered transmission channels of monetary policy and for financial supervisory authorities to regulate banks' risk-taking behaviour.

The remainder of this chapter is organized as follows. Section 3.2 provides a brief review of the rationale for, and summarises existing findings on, the *risk-taking channel*. It also presents an explanation for the working of the *risk-taking channel* in bank lending and its repercussions on the housing market and broader economy. In section 3.3 empirical evidence for the *risk-taking channel* in the U.S. mortgage banking sector is presented. In section 3.4, a baseline DSGE model is developed and, in the following section, the monetary policy transmission is analyzed in the absence of the *risk-taking channel*. In section 3.6, the *risk-taking channel* is accommodated in the baseline model to examine how the transmission effects change in the presence of the channel. Section 3.7 sets out the conclusion.

## 3.2 Risk-taking Channel and Mortgage Lending

This section provides a short summary of the theoretical considerations underlying the *risk-taking channel* and summarises relevant empirical findings. I will then demonstrate the implications of the channel for the mortgage market and its impact on the housing market and the economy as a whole.

### 3.2.1 Rationale and Empirical Findings

The *risk-taking channel* was introduced explicitly by Borio and Zhu (2008) as an additional monetary policy transmission channel. It is defined as follows:

> *the* risk-taking channel *in the transmission mechanism (is) defined as the impact of changes in policy rates on either risk perceptions or risk-tolerance and hence on the degree of risk in the portfolios, on the pricing of assets, and on the price and*

*non-price terms of the extension of funding. (Ibid, pp. 9)*

This issue has received growing interest in academia due to the failure of the global banking system caused partly by the excessive risk-taking behaviour of mortgage suppliers observed in the first half of the last decade. The Fed maintained that the overheated housing market prior the crisis was not associated with past monetary policy decisions (Greenspan, 2010; Bernanke, 2010). However, an alternative possibility was proposed that an accommodative monetary policy stance for the extended period might affect the risk-taking behaviour of economic agents, especially financial intermediaries. Thereafter, the main focus has been on the causal chain or correlation between an easy policy stance and banks' risk-taking. A preliminary consensus has been established that two necessary conditions must be fulfilled: 'too low' interest rates as the first condition and for 'too long' a period as the second one.

The question naturally follows: in what ways does a loose monetary policy stance encourage banks to take more risk? There are three possibilities. The foremost and fundamental driver, from my viewpoint, would be the tendency of 'search for yield' in the period of low interest rates as noted by Rajan (2006) and others. To take an example from the banking sector[6], the yields of bonds are more likely to be lower than these of other investments such as stock and collateralized lending to households. While the exposure to stock is circumscribed within a ceratin level since it is classified as a highly risky asset and hence harmful for satisfying minimum capital requirements set by the BIS (Bank for International Settlements), collateralized lending ensures higher profitability and also limited possible loss in the case of default. These two attractions drive banks to expand lending against housing as collateral by loosening lending criteria and increasing lending to borrowers with low creditworthiness.

Secondly, during a period of low monetary policy rates coupled with moderate economic growth as during the Great Moderation, banks are more likely to neglect the possibility that assets held by them can turn sour or non-performing and borrowers' real income growth can become negative in the future. To apply this reasoning to the mortgage market, if the value

[6] Investment banking or shadow banking is not considered in this example.

of collateral and the income level of borrowers were increasing, then mortgage suppliers would perceive the risk in lending as lower than they would otherwise. The underestimation of risk results mainly from the expectation that robust growth in income and collateral value will persist into the distant future. Finally, as pointed out by the ECB sources, banks are more likely to undertake riskier and more profitable investments as long as interest rates remain low in the belief that the lender of last resort will come to the rescue in order to prevent the overall economy from collapsing. If it were not for the 'too big to fail' myth, preference for a riskier position could be subdued to some extent and the degree of moral hazard could be lessened.[7]

Empirical findings on the *risk-taking channel* has been increasing recently. Drawing on expansive and detailed data on individual bank loans from the Spanish Credit Register in the period from 1984 to 2006, Jiménez *et al* (2008) find that lower overnight lending rates cause banks to loosen lending criteria and expand credit line to borrowers with mediocre credit records despite higher default risk. These findings gain support from Ioannidou *et al* (2009) who provide the evidence that the default probability of bank loans rises and lending to riskier borrowers tends to increase in Bolivia as the U.S. federal funds rates (FFR) decrease.[8] In another study, Altunbas *et al* (2010) investigate whether low interest rates affect the risk position of 643 banks in 15 industrialized countries using balance sheet data for the period from 1998 to 2008. Banks' risk is measured by the expected default frequency (EDF), an indicator for the probability that a company will default in a certain time horizon. They find that the low short-term interest rates for a sustained period caused an increase in banks' default risk. Gambacorta (2009) provides evidence on the negative relationship between interest rates and banks' default risk by using an econometric approach similar to the one employed in Altunbas *et al* (2010).[9] Delis and Kouretas (2011), by consulting the balance sheet information of

[7] Essentially the first and second points are in line with Borio and Zhu (2008) who explain how the *risk-taking channel* works in general instead of focusing on bank lending.

[8] The authors maintain that the U.S. FFR is a proper measure of Bolivian monetary policy stance since over 90 percent of Bolivian deposits and credits are transacted in the U.S. dollar.

[9] The data used is obtained from the balance sheets of 600 banks in Europe and U.S. during the period 2007-2008.

banks in the Euro area during the period 2001-2008, find that the ratio of risky asset value to total asset value, as well as the ratio of non-performing loans to total loans, increased. Maddaloni and Peydró (2011) focus explicitly on the influence of monetary policy rates on relaxed lending standards. By using the responses from bank lending surveys carried out in the Euro area and U.S., they identify the positive influence of an accommodative policy stance on the loosening of lending standards during the period from 2002 Q4 to 2008 Q3.

A similar strand of research in the U.S. has also recently been in the spotlight. Adrian and Shin (2009, 2010b) stress the importance of the role of short-term interest rates in generating business cycle by causing dramatic changes in the banking sector's credit supply. In a recent paper, Adrian and Shin (2010a) introduce the concept of *risk-taking channel* and maintain that banks are liable to estimate risk as lower and hence take a riskier investment position as lower short-term interest rates widen the margin between the interest rate on deposits and return on the assets in the balance sheet. However, their research is theoretical and hence needs sound support from empirical research.

### 3.2.2 Implications of Risk-taking Channel for Mortgage Market and Economy

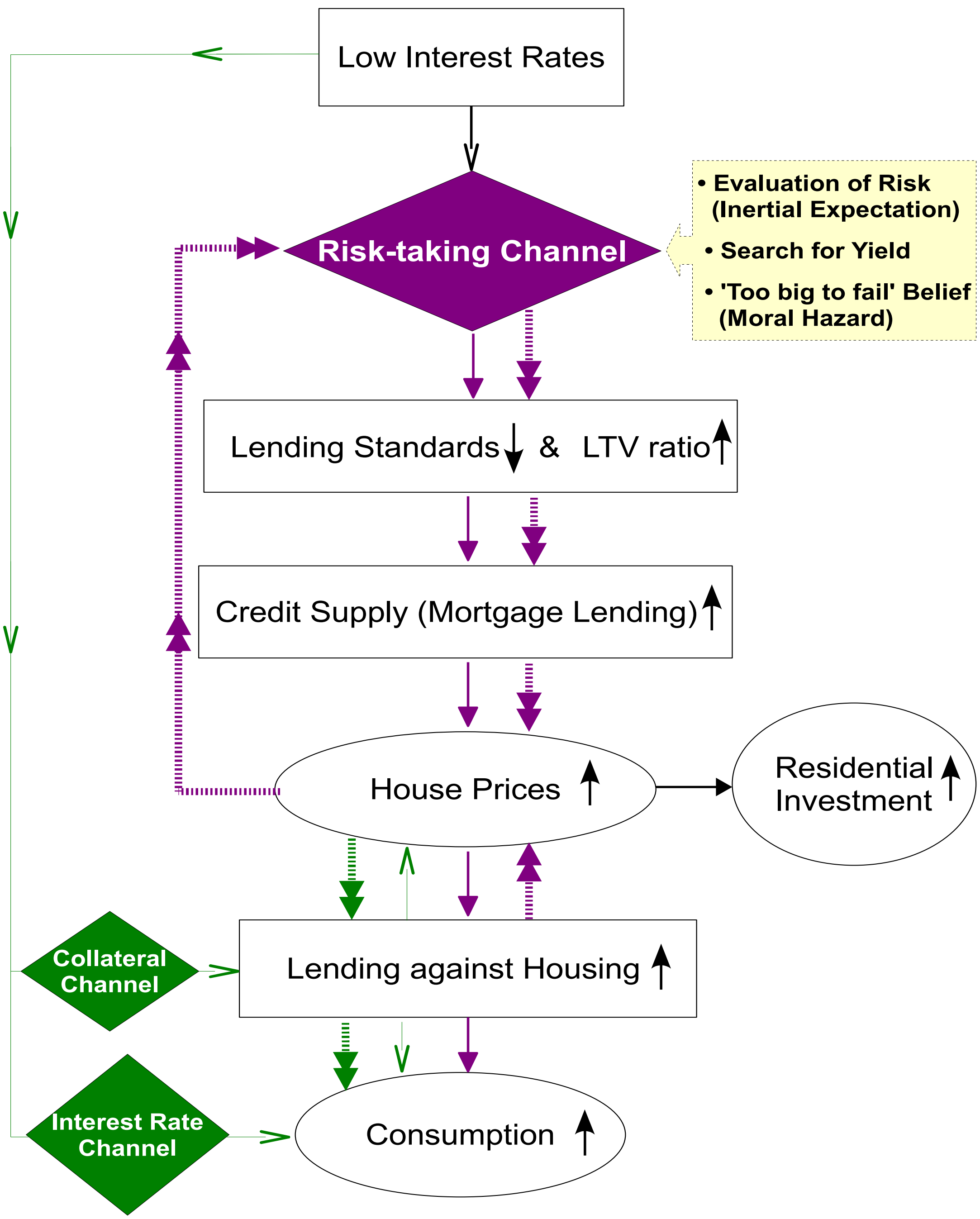
The empirical studies reviewed in the previous sub-section suggest that lower interest rates lead banks to soften lending criteria and supply more credit than they would otherwise. The specific dependent variables in these analyses include the probability of banks' default in the future, the ratio of risky asset value to the total asset value and the percentage of banks tightening their lending standards. Given the importance of the effect of leverage on general consumption and housing purchases, loan-to-value (LTV) ratio needs to be added to the list of measures of banks' risk appetite. The rationale for considering the LTV ratio as a measure of risk-taking attitude is consistent with the rationale for the *risk-taking channel*. During a prolonged period of an accommodative monetary policy stance, collateralized lending to households satisfies the dual targets of profitability and safety. This leads banks to expand lending against housing as collateral by raising the LTV ratio even though the collateral value stays constant. There are additional factors inducing banks to lower the LTV ratio. As long as house price inflation triggered by low interest rates continues, lenders would take the default risk of borrowers less seriously compared with the period of a bearish housing market. Furthermore, if low interest rates are maintained for an extended period, expectation of robust house prices in the future would encourage complacency in evaluating the risk of mortgage lending. Lenders can also decrease the price of lending as long as households' net worth is increasing given the low interest rate environment. As such, the realized appreciation of housing prices and expectation about further increases induce banks to perceive the overall risk of mortgage lending as lower and to increase the LTV ratio. Enhanced credit supply and higher value of housing will persist until interest rates reverse their direction.

The *risk-taking channel* operating in the mortgage market has unambiguous implications for the wider economy. More funds would be available to households than in the absence of the channel. The funds borrowed against housing are spent not only on purchasing houses but also on consuming other durable and non-durable goods. Residential investment increases as the demand for housing expands fueled by ampler liquidity with low borrowing costs. Notable is that once the channel begins to operate, a self-reinforcing feedback loop would come into play between risk-taking, mortgage lending supply, house prices and real economic activity. Figure 3.1 illustrates the causal chain running from low interest rates to the housing market and macroeconomic activities via the *risk-taking channel*.

## 3.3 Empirical Estimation of Risk-taking Channel

In this section, we examine the presence of the *risk-taking channel* in the U.S. mortgage market. Two empirical methodologies are employed: simple regression and VAR approach. However, before conducting the analysis, we first discuss some relevant aspects of the data on the LTV ratio.

**Figure 3.1. Risk-taking Channel in Mortgage Market**




Note: 1. Rectangles and ellipses represent changes in financial and real variables respectively.
2.The thick dashed line represents the feedback effects between the risk-taking channel, housing market and mortgage.

### 3.3.1 Data

There does not exist an officially compiled historical series on the LTV ratio. Hence, one has to depend on work done by other researchers to obtain this database. In this regard, a special comment should be given about the LTV time series estimated by Duca *et al* (2011) for first-time home buyers in the U.S. The series is very useful for researchers in the field of housing since the frequency is very high (quarterly) and the time span extends as far back as 1979.[10] The estimated data can be broadly classified into two types depending on the type of mortgage issuers; private mortgages and all types of mortgages including those from government-sponsored agencies such as the Federal Housing Finance Agency (FHFA). The series for private mortgages is considered more pertinent for an analysis of the *risk-taking channel* since the mortgages from the FHFA omit non-standard loans which convey substantial information on the risk-taking behaviour of private mortgage lenders.

The data series has proven to be highly reliable judging by its close co-movement with the data on the auto loan LTV ratio published officially by the Fed.[11] The property of an automobile as a durable good justifies the comparison. Figure 3.2 shows the long-term series of the two kinds of LTV ratios regarding home mortgages and auto loans, respectively, from 1980 Q1 to 2007 Q4. These two time series appear to have an upward trend, although there is pronounced decoupling between them during the period from 1985 to 1989. Especially after 1990, the co-movement of the two trends is pronounced in the same figure.

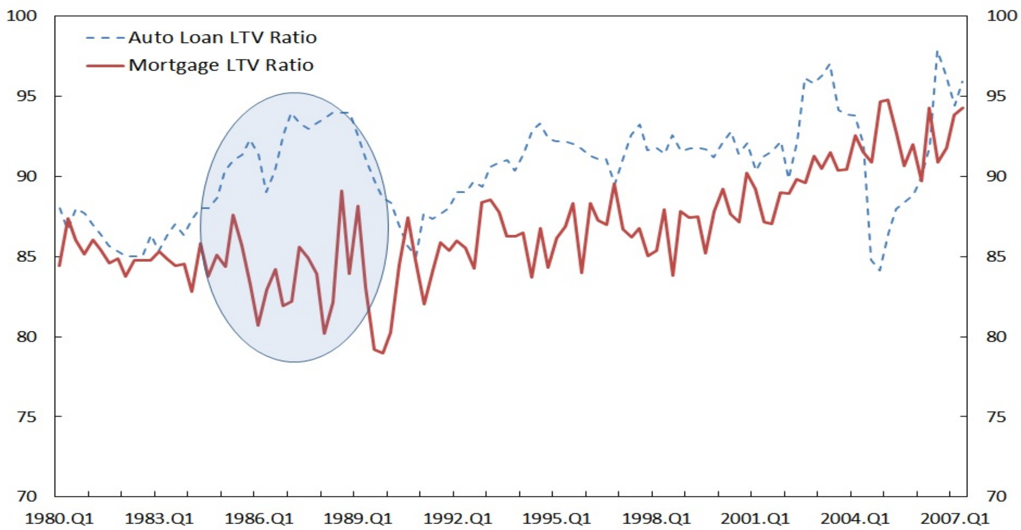
To evaluate the correlation between the trends of both time series, the trend components of each time series are extracted using the Hodrick-Prescott (HP) filter with the smoothing parameter 100,000. The trend components are graphed in Figure 3.3. Not surprisingly, and as expected from the original data series, the correlation coefficient turns out to be 0.9930 which implies a near perfect co-movement. This lends great plausibility to the data series

[10] Using the estimated data, the paper evaluates the influence of credit condition changes on house prices.

[11] The data can be downloaded from the ′Terms of credit′ menu on the webpage of http://www.federalreserve.gov/releases/g19/hist

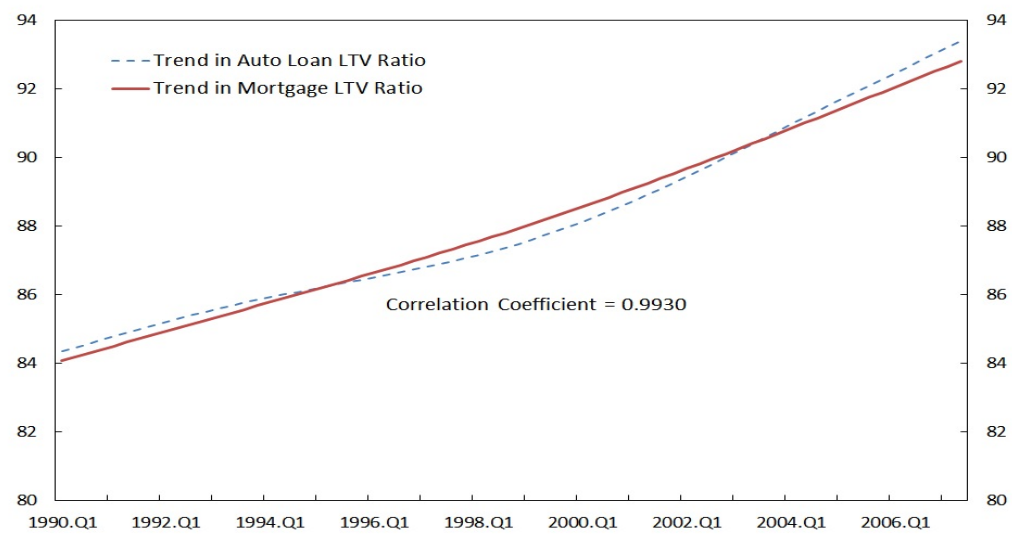
estimated by Duca *et al* (2011) and we will use this in our subsequent estimations.

**Figure 3.2. Auto Loan and Home Mortgage LTV Ratio in U.S.**




Data Source: Federal Reserve, Duca *et al* (2011)

**Figure 3.3. Trend Components of Auto Loan and LTV Ratio**




Data Source: Federal Reserve, Duca *et al* (2011)

### 3.3.2 Estimation

#### 3.3.2.1 Regression Analysis

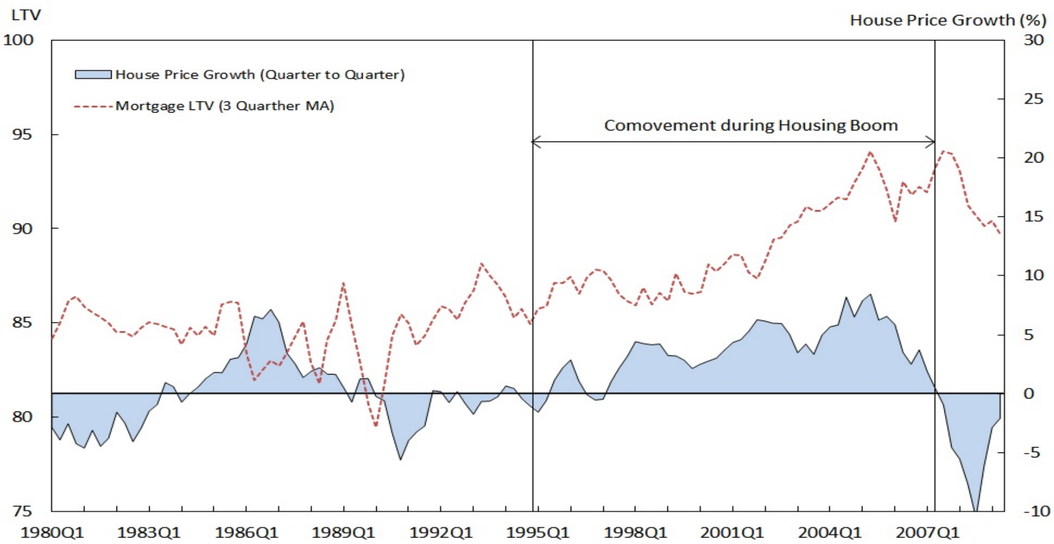
To examine whether the *risk-taking channel* exists or not in the U.S. mortgage market, that is, if lenders take on more risk by increasing the LTV ratio as interest rates decrease, the following regression equation is estimated with the LTV ratio as the dependent variable.

$$LTV_t = \alpha + \beta_1 LTV_{t-1} + \beta_2 FFR_{t-1} + \beta_3 HPG_{t-1} + \epsilon_t \tag{3.1}$$

The determinants of the LTV ratio in the current period, $LTV_t$, includes the one-quarter lagged LTV ratio, $LTV_{t-1}$, the lagged Federal Fund Rates ($FFR_{t-1}$), which are the overnight interest rates fluctuating closely around policy rates, the lagged growth rates of real house prices, $HPG_{t-1}$ which is computed using the National House Price Index (NHPI) published by FHFA. The equation above hypothesizes that mortgage lenders set today's LTV ratio based on the level of short-term interest rates and house price inflation in the previous period while avoiding overly rapid changes by adjusting the LTV ratio in the previous period to a small extent. The inclusion of house price inflation is justified on the basis of the reasoning about the *risk-taking channel*. As house prices continue to rise for a prolonged period, lenders are more likely to focus on the positive side in the distribution of the housing price risk and hence increase the LTV ratio. The apparent positive correlation in Figure 3.4 between the house prices and the LTV ratio in the U.S. from 1995 to 2007 seems to support this speculation.

The regression results for two different time periods are shown in Table 3.1. The first time period for estimation is from 1980 Q1 to 2009 Q2 to utilize all the data on the regression variables. The coefficient of $FFR_{t-1}$, which is of main interest, is significant at the 10% significance level as well as that of $HPG_{t-1}$. The signs of the coefficients are consistent with the *risk-taking channel* hypothesis above; low interest rates and the robust housing market induce lenders to assume more risk by raising the LTV ratios and become more willing to

**Figure 3.4. Mortgage LTV Ratio and House Price Growth in U.S.**




Data Source: Federal Reserve Board, Duca *et al* (2011)

supply credit.

**Table 3.1. Estimation of LTV Equation using Level Data**

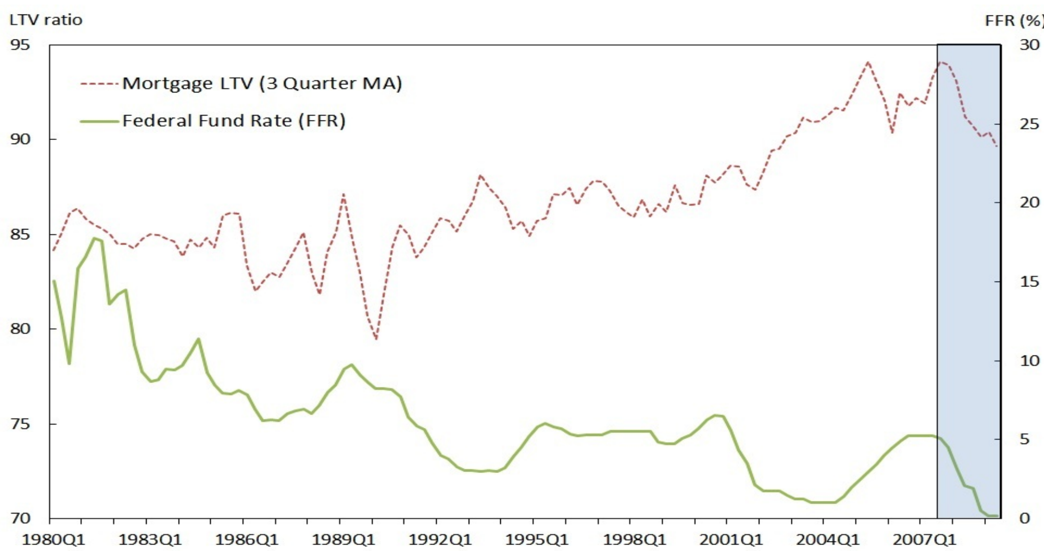
| | 1980 Q1 - 2009 Q2 | | | 1985 Q1 - 2007 Q2 | | |
|---|---|---|---|---|---|---|
| | value | $t$-statistic | $p$-value | value | $t$-statistic | $p$-value |
| $\alpha$ (constant) | 28.855*** | 4.701 | 0.000 | 40.392*** | 5.124 | 0.000 |
| $\beta_1$ ($LTV_{t-1}$) | 0.676*** | 9.917 | 0.000 | 0.558*** | 6.466 | 0.000 |
| $\beta_2$ ($FFR_{t-1}$) | -0.135* | -1.974 | 0.051 | -0.425*** | -3.195 | 0.002 |
| $\beta_3$($HPG_{t-1}$) | 0.104*** | 1.729 | 0.087 | 0.146* | 1.692 | 0.094 |
| | $R^2$ = 0.643 , $DW$ = 2.283 | | | $R^2$ = 0.649, $DW$ = 2.153 | | |

In the regression for the second time period from 1985 Q1 to 2007 Q2, the coefficients of these two variables prove to be significant again.[12] Notably, the coefficient of $FFR_{t-1}$ is significant even at the 1% significance level. The statistical significance improves since the new time period excludes the data from 2007 Q2 to 2009 Q2. Over theose two years, the

[12] The motivation for starting the sample period from 1985 lies in the possibility that the financial liberalization might begin exerting its real influence only after the mid-1880s. Moreover, the samples after the breakout of the sub-prime crisis are excluded because the relationship between interest rates and house prices in the post-crisis period is positive which is abnormal from the viewpoint of the established empirical findings.

housing market crash subdued the LTV ratio despite appreciable decreases in policy rates, as the shaded area in Figure 3.5 illustrates. Overall, the two sets of regression results corroborate the existence of the *risk-taking channel* in the U.S. and support inclusion of the channel when we inspect the effects of monetary policy decisions on the mortgage market. In terms of macroeconomic modeling, this implies that the LTV ratio should be allowed to vary based on changes in interest rates and house prices to analyze the full aspects of monetary policy transmission.

**Figure 3.5. Mortgage LTV Ratio and Federal Fund Rates in U.S.**




Data Source: Federal Reserve Board, Duca *et al* (2011)

Since the equations estimated using the level data are not suitable for the log-linearized DSGE model to be presented in the following section, a separate equation needs to be estimated using detrended or demeaned data. As the overall fitness of regression using the detrended data by HP filter is not satisfactory, demeaned data are used for all variables in the regression equation. Demeaning implies that the long-term average is assumed to be the steady state of each variable. The regression equation to be estimated is given below.[13]

$$\widehat{LTV}_t = \gamma_1 \widehat{LTV}_{t-1} + \gamma_2 \widehat{FFR}_{t-1} + \gamma_3 \widehat{HPI}_{t-1} + \epsilon_t \tag{3.2}$$

where the hatted variables represent percentage deviation from the steady state and $HPI$ represents the level of the house price index from the FHFA (instead of the growth rate denoted by $HPG$ in the preceding regression analysis).[14]

**Table 3.2. Estimation of LTV Equation using Demeaned Data**

| | 1980 Q1 - 2007 Q2 | | | 1995 Q1 - 2007 Q2 | | |
|---|---|---|---|---|---|---|
| | value | $t$-statistic | $p$-value | value | $t$-statistic | $p$-value |
| $\gamma_1$ ($\widehat{LTV}_{t-1}$) | 0.427*** | 4.885 | 0.000 | 0.329* | 2.012 | 0.036 |
| $\gamma_2$ ($\widehat{FFR}_{t-1}$) | -0.577 | -1.335 | 0.185 | -3.207*** | -4.370 | 0.000 |
| $\gamma_3$ ($\widehat{HPI}_{t-1}$) | 0.128*** | 4.568 | 0.000 | 0.181*** | 6.235 | 0.000 |
| | $R^2$ = 0.676 , $DW$ = 2.045 | | | $R^2$ = 0.792, $DW$ = 2.214 | | |

Table 3.2 shows the two sets of regression results for the different time periods. For the first time period from 1980 Q1 to 2007 Q2, the coefficient of $\widehat{FFR}_{t-1}$ turns out to be insignificant even at the 10% significance level, whereas it is highly significant for the second time period from 1995 Q1 to 2007 Q2. Based on the statistical significance, the regression equation for the latter time period is set as the benchmark LTV equation to be incorporated into the DSGE model. To express it in an equation form, the estimated equation of (3.2) is given by

$$\widehat{LTV}_t = 0.211\, \widehat{LTV}_{t-1} \ - 3.207\, \widehat{FFR}_{t-1} \ + 0.181\, \widehat{HPI}_{t-1} \ + \epsilon_t \tag{3.3}$$

The estimated coefficients imply that lenders respond more aggressively to the deviation

[13] Not only for the purpose of obtaining a dynamic solution to the model but also by the assumption of naive type of backward-looking expectation, the dependent variables take only one-period lagged terms.

[14] A separate regression equation is estimated which includes *realized* federal funds rates instead of *nominal* ones. The estimation results reveal that the magnitude of the coefficient of $\gamma_2$ is slightly below the level obtained by the estimation of the equation including nominal $FFR$. This implies that the regression result is robust.

of short-term rates from the steady state than that in house prices. A basic intuition is provided by the fact that the *risk-taking channel* induces low interest rates to influence lenders' behaviour in more ways than house prices do. In a low interest rate environment, lenders expect higher house prices, search for higher yield and estimate downside risk to collateral as lower.

The error term, $\epsilon_t$, which is a shock to the LTV process, retains an important implication for the housing market. The shock encompasses, for instance, the changes in regulation relating to the discretion of mortgage lenders to decide on their LTV ratio, the invention of new lending products such as exotic mortgages, and changes in the degree of information asymmetry between lenders and borrowers. For example, if the financial authorities grant more latitude to mortgage lenders in determining the LTV ratio or allow them to sell mortgage products with a smaller downpayment, then the ratio will increase given a specific level of house prices and interest rates.

#### 3.3.2.2 VAR Analysis

A VAR analysis is now employed to examine the existence of the risk-taking channel. A specific representation of the relationship to be identified by VAR will differ from one obtained through regression analysis between the three variables of interest, i.e. short-term interest rates, house prices and the LTV ratio. However, as each variable in a VAR model is also expressed in a similar type of equation to a regression equation with the LTV ratio as a dependent variable, the same qualitative aspect of the *risk-taking channel*, if it exists, can be ascertained through an impulse response analysis. The specific VAR model is defined as below.

$$\Gamma y_t = c + A(L) y_t + \Sigma e_t \tag{3.4}$$

where $y$ is a vector of endogenous variables, $A(L)$ is the parameter matrix in the lag operator $L$, and $\Sigma$ is the variance-covariance matrix of the structural shocks. The vector $y$ includes three endogenous variables, (i) the federal funds rates denoted by $INT$, (ii) the growth rates of the house price index, $HPG$, and (iii) the LTV ratio. The model is estimated using the same data as in the regression analysis from 1980 Q1 to 2007 Q2. In order to let the impulse response of the LTV ratio be more sensitive to a monetary policy shock, the data after 2007 Q2 is excluded.

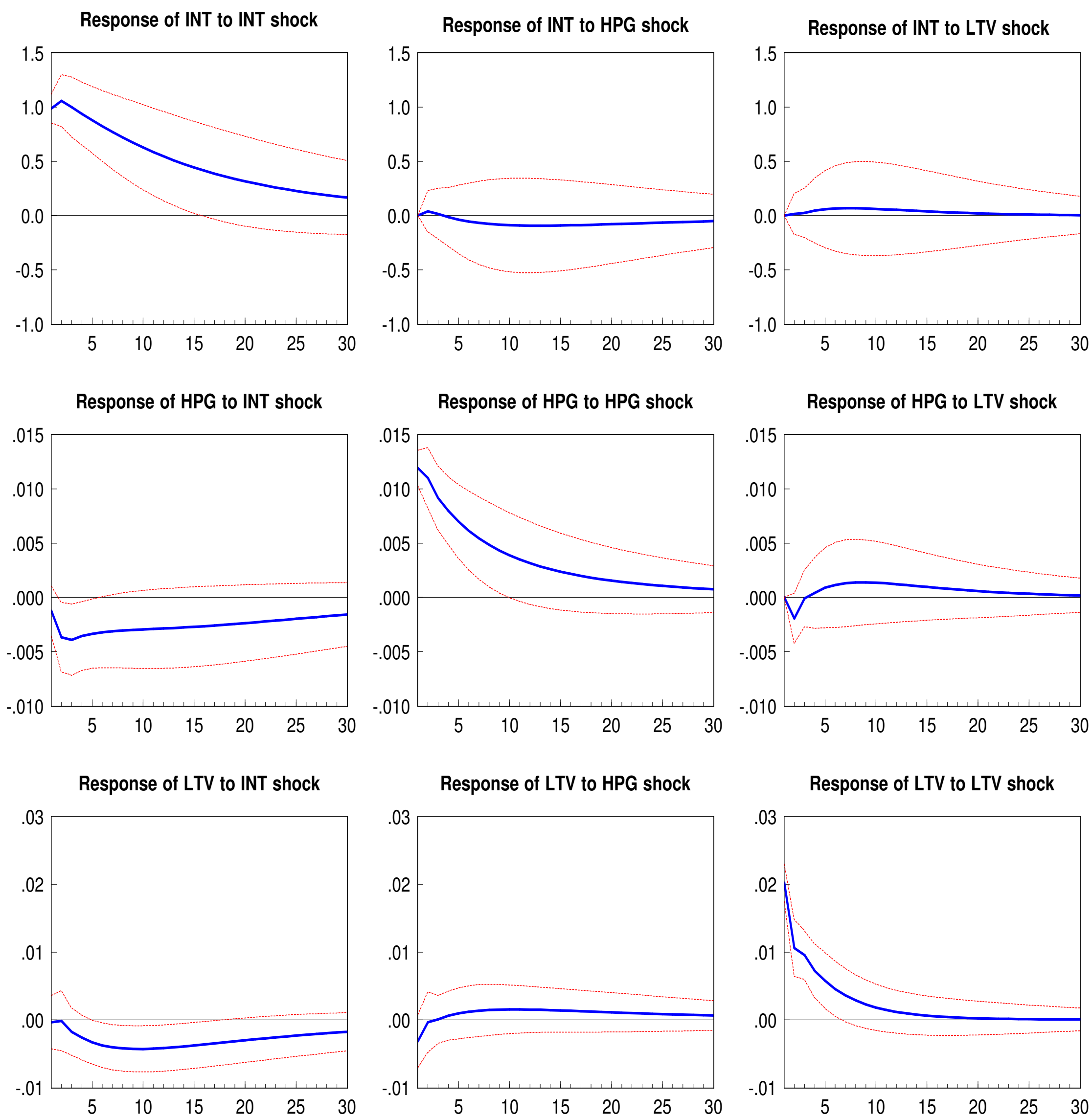
The three structural shocks from the model are identified through Cholesky decomposition which include a monetary policy shock and shocks to house prices and the LTV ratio. The endogenous variables are ordered as follows:

$$y_t = [INT_t,\ HPG_t,\ LTV_t] \tag{3.5}$$

This recursive identification scheme restricts interest rates, $INT$, from responding contemporaneously to the house price growth ($HPG$) and the LTV ratio. In a similar vein, LTV bears no influence on $HPG$ in the same quarter. These restrictions are harmonious with the fundamental purpose of this VAR analysis for diagnosing the existence of the *risk-taking channel*, despite the common observations that these three variables exert influences on each other simultaneously. The lag order of the model is set as 2 based on Schwarz information criterion and the $F$-statistics for model reduction.

Figure 3.6 includes the impulse responses of each endogenous variable to the three structural shocks. Our main interest lies in whether the LTV ratio responds negatively to a monetary policy shock. In addition, we can see whether LTV reacts positively to $HPG$ as indicated by the results of the regression analysis presented above. The left panel of the bottom row in the same figure is of primary interest to us. It shows that the response path of the LTV ratio to a monetary policy shock and it is consistent with the hypothesis presented above on the *risk-taking channel*. A positive increase of 100bp in short-term interest rates leads LTV to decrease by a maximum of 0.5%. This implies that an expansionary monetary policy shock will result in higher the LTV ratio through the *risk-taking channel*. The impulse response

**Figure 3.6. Impulse Response from VAR Analysis**




Note: 1. $INT$ and $HPG$ denote Federal Fund Rates and the growth rate of realized NHPI.
2. Confidence bands are based on the 95% significance level.

Data Source: Federal Reserve, Federal Housing Finance Agency, Duca *et al* (2011)

function is consistent with the regression results presented above.

The second panel in the bottom row of that figure shows that a positive shock to house prices increases the LTV ratio. The result also confirms the legitimacy of the regression result despite the relatively subdued magnitude of the response of the LTV ratio. As stated previously, lenders are likely to underestimate the risk latent in housing-collateralized lending as housing prices appreciate. Another notable feature of this impulse response analysis is the response of $HPG$ to a contractionary monetary policy shock. The first panel in the middle row is consistent with recent findings using a VAR approach (Bjørnland and Jacobsen, 2010; Musso *et al*, 2010) in that an increase in short-term interest rates induces housing prices to deflate.

## 3.4 Developing a DSGE Model

In this section, a DSGE model will be developed to analyze the influences of the *risk-taking channel* on the overall economy. The model features two types of households which are patient households (savers) and impatient households (borrowers). Households supply firms with labor as an input to production and spend their labor income to accumulate residential housing and consume other goods. Savers who are more patient than borrowers save a fraction of their labor income and lend the funds to borrowers facing a borrowing constraint. In return for the funds lent, savers earn interest from borrowers. Firms produce wholesale consumption goods using only labor. Monopolistically competitive retailers buy the intermediate goods from firms and price these goods for sale. However, as in Calvo (1983), only a certain proportion of retailers can adjust retail prices subject to the predetermined probability that a random signal arrives. The restriction on price re-optimization introduces nominal rigidities into the model.

A simplifying assumption is introduced regarding the use of housing. Housing in this economy is solely for residential purposes unlike that in Iacoviello (2005) and Iacoviello and Neri (2010) where it is used for production purposes as well. In these two papers, the production technology comprises housing as an input. This simplification makes the model consistent with the estimation of the LTV ratio equation in Section 3 since data comprising only home mortgages was used for the estimation.[15]

### 3.4.1 Patient Households

There is a continuum of identical patient households (savers) denoted by $P$. A representative patient household maximizes a lifetime utility function given as below.

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left[ \ln c_t^P + j \ln h_t^P - \frac{(L_t^P)^{\varphi}}{\varphi} + \chi \ln \left( \frac{M_t^P}{P_t} \right) \right] \tag{3.6}$$

Consumption $c_t^P$, holding of housing $h_t^P$ and real money balances $\frac{M_t^P}{P_t}$ affect the level of utility positively whereas hours worked $L_t^P$ brings disutility to households. $\beta_P$ refers to the discount factor with $0 < \beta_P < 1$, $j$ and $\chi$ denote preference for housing and real money balances respectively, and $\varphi$ is related to the elasticity of labor supply. The budget constraint faced by patient households when maximizing expected utility is given as follows.

$$c_t^P + q_t(h_t^P - h_{t-1}^P) + s_t^P = w_t^P L_t^P + \frac{R_{t-1} s_{t-1}^P}{\pi_t} + F_t + T_t^P - \Delta(\frac{M_t^P}{P_t}) \tag{3.7}$$

where $q_t$ denotes real house prices ($\frac{Q_t}{P_t}$), $s_t$ is real savings, $w_t^P$ is real wages. Patient households consume goods and accumulate housing while saving a certain fraction of the total income which comprises labor income, real interest income $\frac{R_{t-1}\, s_{t-1}^P}{\pi_t}$, dividends from the retailers ($F_t$) and transfer from the central bank ($T_t$).[16] Increments in real money balances are funded by the various sources of total income.

[15] If data on the LTV ratio of business properties were available, this baseline model can be expanded to include an entrepreneurial sector. We leave this for future research.

[16] Nominal interest income from lending $s_t$ to borrowers at the previous period is $R_{t-1}S_{t-1}$ where $S_{t-1}$ is nominal savings equal to $P_{t-1}s_{t-1}$. Hence nominal interest income from lending the savings can be rewritten as $R_{t-1}P_{t-1}s_{t-1}$. Dividing it with overall price level $P_t$ renders real interest income at the current period $(R_{t-1}s_{t-1}P_{t-1})/P_t$. Since $P_{t-1}/P_t$ is the reciprocal of the gross inflation rate $\pi_t = P_t/P_{t-1}$, the real interest income at the current period is expressed finally as $(R_{t-1}s_{t-1}^P)/\pi_t$.

### 3.4.2 Impatient Households

The group of impatient households (borrowers) denoted by $B$, also has unit mass and maximizes the same type of utility function as savers.

$$E_0 \sum_{t=0}^{\infty} \beta_B^t \left[ \ln c_t^B + j \ln h_t^B - \frac{(L_t^B)^{\varphi}}{\varphi} + \chi \ln \left( \frac{M_t^B}{P_t} \right) \right] \tag{3.8}$$

However, the discount factor of the impatient households is less than that of the patient ones, i.e. $\beta_B < \beta_P$. This condition ensures that the borrowing constraint for the impatient households binds near the steady state with reasonably small shocks.[17] The budget constraint is different from that of savers only in that impatient households are the borrowing entities and pay interest to savers.

$$c_t^B + q_t(h_t^B - h_{t-1}^B) + \frac{R_{t-1} b_{t-1}^B}{\pi_t} = b_t^B + w_t^B L_t^B + T_t^B - \Delta \left( \frac{M_t^B}{P_t} \right) \tag{3.9}$$

where $b_t$ refers to the debt owed to patient households.

Additionally and importantly, the impatient households are subject to a borrowing constraint the role of which lies at the heart of propagation and amplification of a monetary policy shock in this model. The impatient households provide the current housing stock as collateral and borrow funds against the expected value of the collateral in the next time period. However, mainly because of the uncertainty latent in future house prices and borrowers' ability to repay the debt, the impatient households are entitled to borrow only a fraction of the total collateral value. To express the constraint,

$$b_t \leq m_t \, E_t\left(\frac{q_{t+1} \; h_t^B \; \pi_{t+1}}{R_t}\right) \tag{3.10}$$

This borrowing constraint implies the total amount of real debt should be less than a

[17] Appendix B-1 proves that the borrowing constraint binds at the steady state.

fraction of the discounted expected value of the housing provided as collateral.[18] $m_t$ is the the LTV ratio with $0 < m_t < 1$ and the multiplicative term $m_t \, E_t \left( q_{t+1} \, h_t^B \, \pi_{t+1} / R_t \right)$ can be considered as the upper bound of the collateral value which lenders can secure in redeeming a possible default in the following period. Put differently, $(1 - m_t)$ fraction of the collateral value is considered by the lenders as the minimum sum of various costs to be incurred by a default such as the cost for legal proceedings, foreclosing and reselling collateral.

Even though $m_t$ is time-varying in practice and determined by the patient households in the model with the *risk-taking channel* to be presented later, we assume for the moment it is fixed as $\overline{m}$ to provide a benchmark for measuring the effect of the *risk-taking channel.* Henceforth, I will designate the version of the model with the fixed LTV ratio as the *baseline model* and the LTV-endogenized version as the *risk-taking model.*

### 3.4.3 Wholesale Goods Firms

The firms produce wholesale goods $Y_t$ by hiring labor from households using the following technology in which labor is a unique input.

$$Y_t = A \; (L_t^P)^{\alpha} \; (L_t^B)^{(1-\alpha)} \tag{3.11}$$

where $A$ represents total factor productivity and $\alpha$ is the labor income share of patient households. Since the main focus of the analysis is put on the transmission effects of the shocks to monetary policy and the LTV ratio, we ignore technological shocks and set $A$=1 for the purpose of simplicity. The wholesale firms maximize profit, i.e. revenue of $Y_t/X_t$ less cost of $w_t^P L_t^P + w_t^B L_t^B$, as below.

$$\max_{L_t^P, L_t^B} \; \frac{Y_t}{X_t} - w_t^P L_t^P - w_t^B L_t^B \tag{3.12}$$

where $X_t$ is the markup of final goods over wholesale goods defined by a ratio of retail prices

[18] In nominal terms, $B_t \leq m_t E_t \left( \frac{Q_{t+1} h_t}{R_t} \right)$, and if both sides are divided by $P_t$, $\frac{B_t}{P_t} \leq m_t E_t \left( \frac{h_t}{R_t} \frac{Q_{t+1}}{P_{t+1}} \frac{P_{t+1}}{P_t} \right)$

to wholesale ones, $P_t/P_t^w$.

### 3.4.4 Retailers

To introduce price rigidities into the model, monopolistic competition and Calvo-type price optimization are assumed at the retail level as in the standard New Keynesian model. A continuum of retailers of mass unity buy wholesale goods from the firms at $P_t^w$ and sell them to consumers at $P_t$. Aggregate final goods index ($Y_t^F$) is the integration of demand of each retailer, indexed by $i$, for intermediate goods as follows.

$$Y_t^F = \left( \int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} \, di \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.13}$$

where $\varepsilon$ represents the elasticity of substitution among differentiated intermediate goods and is over unity ($\varepsilon > 1$). The aggregate price index also derives from integration of the individual price index which the retailers are facing.

$$P_t = \left( \int_0^1 P_t(i)^{1-\varepsilon} \, di \right)^{\frac{1}{1-\varepsilon}} \tag{3.14}$$

Given these two aggregate indices, retailers maximize the expected lifetime utility function under a standard type of budget constraint. The maximization yields the following individual demand function for final goods which each retailer faces.

$$Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t^F \tag{3.15}$$

Taking the demand function and the wholesale price, $P_t^w$, as given, each retailer chooses the optimal price $P(i)_t^*$ to maximize the current value of the profit made under the condition that the chosen price remains effective. However, only a fraction, 1-$\theta$, of retailers receive random signals during each period and reset the prices while the remaining fraction $\theta$ maintains the same price as in the previous period. The optimal price can be obtained by solving the following problem.

$$\max_{P(i)_t^*} \sum_{k=0}^{\infty} \theta^k E_t \Big\{ \Lambda_{t,k} \Big( \frac{P_t^*(i)}{P_{t+k}} - \frac{X}{X_{t+k}} \Big) Y_{t+k}^*(i) \Big\} = 0 \tag{3.16}$$

where $Y_{t+k}^*(i) = (P_t^*(i)/P_{t+k})^{-\varepsilon} Y_{t+k}$ is the demand for each retailer's differentiated goods and $\Lambda_{t,k} = \beta_P(c_t^P/c_{t+k}^P)$ is the usual stochastic discount factor of the patient household. Without price rigidities, $\theta = 0$, the first order condition of this maximization problem boils down to the condition that the optimal price $P(i)_t^*$ needs to be equalized to the real marginal cost times the desired markup $X = \frac{\varepsilon}{\varepsilon - 1}$. Retailers rebate profits $F_t = (1 - 1/X_t)Y_t$ to patient households. The first order condition of the maximization problem is given as below.

$$P_t^* = X \sum_{k=0}^{\infty} \left[ \frac{(\theta\beta)^k E_t \left( \Lambda_{t,k} Y_{t+k}^{*f} P_{t+k}^{-1} \right)}{\sum_{k=0}^{\infty} (\theta\beta)^k E_t \left( \Lambda_{t,k} Y_{t+k}^{*f} P_{t+k}^{-1} \right)} \right] E_t \left( \frac{1}{X_{t+k}^n} \right) \tag{3.17}$$

Under the Calvo pricing environment, the aggregate price dynamics of the economy is as follows.

$$\pi_t^{1-\varepsilon} = \theta + (1-\theta) \left( \frac{P_t^*}{P_{t-1}} \right)^{1-\varepsilon} \tag{3.18}$$

where $\pi_t$ refers to gross inflation $\frac{P_t}{P_{t-1}}$. Linearizing the equation (3.17) around the steady state and combining it with (3.18) above yields the standard New Keyensian Phillips Curve (NKPC).[19]

### 3.4.5 Monetary Policy

In order to close the model, the central bank is assumed to determine nominal policy rates $R_t$ in response to the deviations of inflation and output from the desired level. The specific

[19] A detailed description of the derivation of NKPC is given on pp. 43-49 of Gali (2008).

type of the Taylor rule is given by

$$R_t = R_{t-1}^{r_R} \left( \pi_{t-1}^{1+r_\pi} \left( \frac{Y_{t-1}}{Y} \right)^{r_Y} \overline{rr} \right)^{1-r_R} e_t^R \tag{3.19}$$

where $\overline{rr}$ and $Y$ denote the steady-state real interest rate and output respectively, and $e_t^R$ is an independently and identically distributed monetary policy shock with zero mean and variance $\sigma_R^2$. The exponent $r_R$ represents the degree of inertia in adjusting policy rates in practice.

### 3.4.6 Equilibrium

If the necessary conditions for optimization and a set of market clearing conditions are satisfied, the model reaches a unique stationary equilibrium in the absence of shocks to the system.[20] The market clearing conditions are for the housing market, $H = h_t^P + h_t^B$, the total output, $Y_t = c_t^P + c_t^B$, and the lending market, $s_t = b_t^B$. The housing stock is assumed to be fixed for simplicity. As stated above, impatient households borrow up to the maximum amount savers are willing to lend. By linearizing the set of first-order conditions and market-clearing ones around the steady state, the baseline model boils down to a system of 14 log-linearized equations as presented in Appendix B-3.

## 3.5 Analysis of Monetary Policy Transmission in Baseline Model

### 3.5.1 Parameter Values for Calibration

To conduct a qualitative analysis of the monetary policy transmission using the baseline model, I choose specific values for parameters based mainly on Iacoviello and Neri (2010) and related papers with a similar motivation and model structure, for example, Iacoviello (2005), Calza *et al* (2009) and Gerali *et al* (2010). The number of parameters to calibrate is 12 and

[20] Appendix B-2 includes the necessary conditions for each sector.

the chosen values of the parameters are listed in Table 3.3.

**Table 3.3. Calibrated Parameters**

| Parameter | Value | Description |
|---|---|---|
| Households | | |
| $\beta_P$ | 0.99 | Patient households' discount factor |
| $\beta_B$ | 0.95 | Borrowers' (Impatient households') discount factor |
| $\varphi$ | 1.01 | Labor supply aversion |
| $j$ | 0.12 | Weight on housing in households' utility function |
| $\alpha$ | 0.64 | Labor income share of patient households |
| Price Rigidities | | |
| $X$ | 1.05 | Steady-state gross markup |
| $\theta$ | 0.75 | Probability of maintaining prices |
| TFP | | |
| $A$ | 1.00 | Total Factor Productivity |
| Monetary Policy | | |
| $r_R$ | 0.73 | Smoothing parameter of the Taylor rule |
| $r_\pi$ | 0.27 | Inflation coefficient of the Taylor rule |
| $r_Y$ | 0.13 | Output gap coefficient of the Taylor rule |
| the LTV ratio | | |
| $\overline{m}$ | 0.87 | LTV ratio |

The values of the parameters in Table 3.3 are somewhat different from those in other studies. For examples, Gerali *et al* (2010) sets the impatient households' discount factor $\beta_B$ to be 0.98 and Gali (2008) sets the price rigidity parameter $\theta$ to be 0.66. However, the differences in these parameter values do not substantially affect the quantitative aspects of the baseline model analysis. Furthermore, the choice of the parameter values specified on Table 3.3 ensures a proper solution to the model which is similar to that one used in , following Iacoviello and Neri (2010). Given the prime role of the borrowing constraint, it is worth elaborating on the level of long-term average the LTV ratio. There have been few statistical sources for calculating a long-term average the LTV ratio which can be considered a steady-state value for the parameter $\overline{m}$. As there is no consensus on the level of average $\overline{m}$, researchers have used different values for it. Referring to Table 3.4 in respect of the U.S., Monacelli (2008) sets the annual average of the LTV ratio as 0.75 for the period 1952-2005, Iacoviello (2005) chooses 0.55, while Iacoviello and Neri (2010) use 0.85. For the Euro area, Calza *et al* (2009) use 0.7.

**Table 3.4. Average LTV Ratio for Home Mortgage**

| Literature | the LTV ratio | Period | Country | Data Source |
|---|---|---|---|---|
| Calza *et al*(2009) | 0.70[1)] | - | Euro Area | various sources[2)] |
| Iacoviello (2005) | 0.55 | - | U.S. | - |
| Iacoviello and Neri (2010) | 0.85 | 1973-2006 | U.S. | Finance Board's Monthly Survey |
| Monacelli (2007) | 0.75 | 1952-2005 | U.S. | Federal Housing Finance Board |

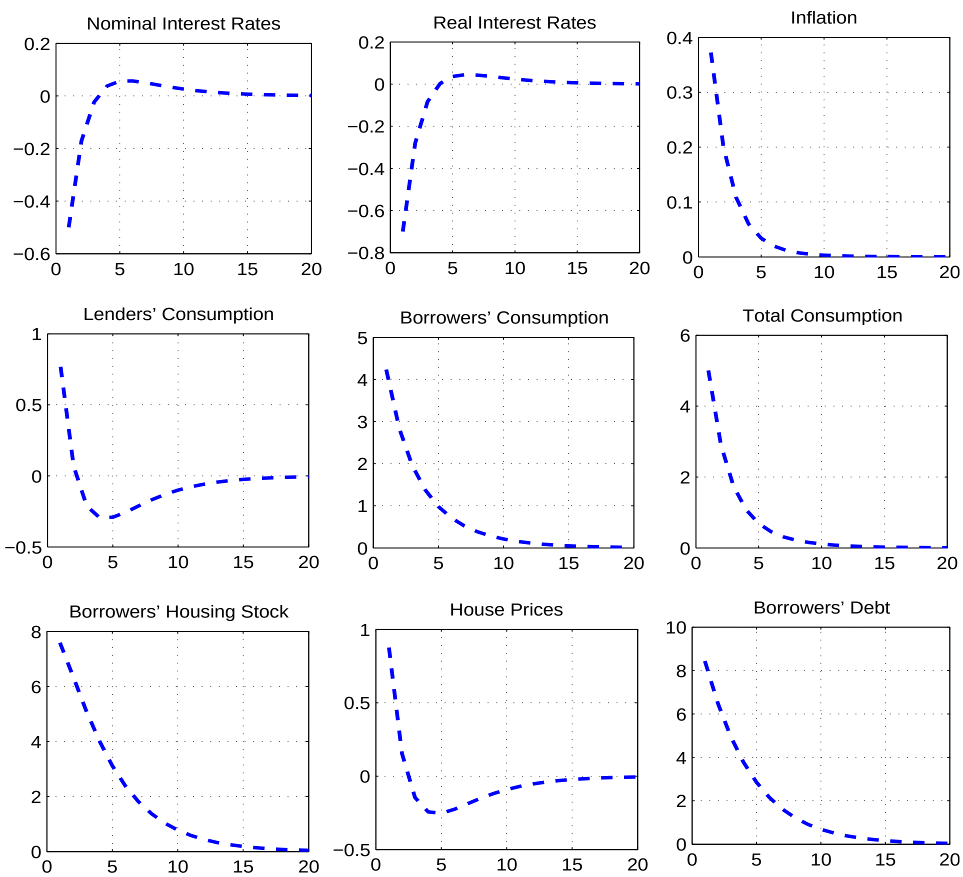
Note: 1) Gerali *et al* (2010) follows the same value of Calza *et al*(2009).
2) For more details, see the Table 1. on pp. 38 in the paper.

In contrast to the literature mentioned above, I used the quarterly LTV data estimated by Duca *et al* (2011) for the U.S. in the previous section. The average of the quarterly LTV ratio from 1980 Q1 - 2008 Q4 is 0.87 which is close to that in Iacoviello and Neri (2010).

### 3.5.2 Impulse Response to Monetary Policy Shock

I will focus on the impulse responses of the main variables of interest to a monetary policy shock: consumption, house prices and debt. The main task of this analysis is in examining if the *risk-taking transmission channel* of monetary policy generates enhanced effects on the paths of these variables. Figure 3.7, in which the time period is one quarter, plots impulse responses to an expansionary monetary policy shock, i.e. a negative shock to nominal interest rates ($R_t$). The transmission process starts with a decrease in $R_t$ which reduces the real in-

**Figure 3.7. Impulse Responses to a Monetary Policy Shock**




Note: The $y$-axis measures percent deviation from the steady state.

terest rate by the Taylor principle. The sufficient condition for satisfying the Taylor principle, as clarified by Bullard and Mitra (2002), is $r_\pi > 1$ in the Taylor rule specified above which implies that real interest rates rise with an increase in the nominal interest rates.

Lower level of real interest rates induce households to expand consumption. In particular, the interest rate channel exerts a stronger influence on the consumption of impatient households than patient ones. The assumption that the discount factor of impatient households is lower than that of patient households implies the former has an incentive to increase current consumption by expanding their borrowing. Another transmission mechanism operates through the changes in house prices caused by an upward pressure on demand in the housing market. As the impatient households spend the additional funds borrowed not only in consuming final goods but also in buying houses, housing prices increase. In turn, the appreciation in the collateral value increases the maximum amount the impatient households can borrow. Owing to this so-called equity withdrawal effect, households again can consume more than previously. This second channel is an application of the *credit cycle* in Kiyotaki and Moore (1997) to the housing market and analogous to the *financial accelerator mechanism* in Bernanke *et al* (1999). These two channels, the *interest rate channel* and *house price channel*, compose the transmission mechanism of monetary policy in Iacoviello (2005) and explain why the impatient households' consumption deviates further from the steady state than that of patient households.[21] [22] These two transmission channels can be illustrated by the following causal flows in which hatted variables denote percent deviations from the steady state.

■ Interest Rate Channel

- Patient Households : $\hat{R}_t \downarrow \longrightarrow \hat{rr}_t \downarrow \longrightarrow \hat{c}^P_t \uparrow$ and $\hat{s}^P_t \downarrow$
- Impatient Households : $\hat{R}_t \downarrow \longrightarrow \hat{rr}_t \downarrow \longrightarrow \hat{b}^B_t \uparrow \longrightarrow \hat{c}^B_t \uparrow$

■ House Price Channel: Equity Withdrawal Effect

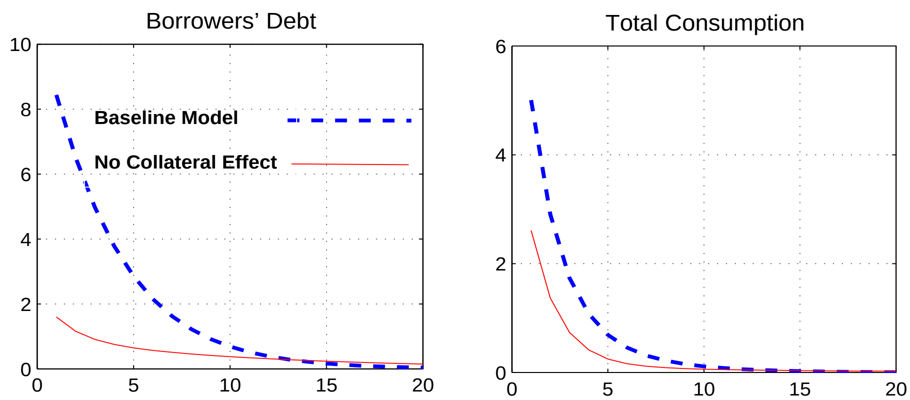
- Impatient Households $\quad \hat{R}_t \downarrow \longrightarrow \hat{rr}_t \downarrow \longrightarrow \hat{b}^B_t \uparrow \longrightarrow \hat{q}_t \uparrow \longrightarrow b^B_t \uparrow\uparrow \longrightarrow \hat{c}^B_t \uparrow$

To get an idea of the quantitative influence of the equity withdrawal effect, I compare the impulse response of consumption in the baseline model with that from the model in which impatient households cannot borrow with housing as collateral. Figure 3.8 juxtaposes the impulse responses of consumption to a positive monetary policy shock from the baseline model with that of the model without a borrowing constraint. As shown in the same figure, the impatient households in the economy without equity withdrawal borrow and consume less than they would otherwise. This means that a monetary policy shock is amplified through borrowing against collateral in the baseline model.

[21] The term *house price channel* is sometimes termed the *collateral channel*.

[22] There is one more channel titled the *debt deflation channel* in Iacoviello(2005).

**Figure 3.8. Comparison of Impulse Responses of Consumption**




Note: The $y$-axis measures percent deviation from the steady state.

## 3.6 Effects of Risk-taking Channel in Mortgage Market

In this section, I will examine whether the *risk-taking channel* in the presence of a positive monetary policy shock generates more volatile paths of the main variables relative to the baseline model. With this in mind, the regression equation for the *risk-taking channel* estimated in Section 3 is incorporated into the baseline model. Endogeneizing the LTV ratio also allows us to examine how a shock to this ratio affects the whole economy.

### 3.6.1 Monetary Policy Shock

#### 3.6.1.1 Backward-looking LTV Ratio Decision Rule

The main hypothesis of this analysis is that the *risk-taking channel* intensifies the effects of a monetary policy shock in the baseline model since lenders raise their LTV ratio in reaction to the shock. Accordingly, impatient households can borrow more than they would otherwise and increase their consumption and holding of housing stock. By incorporating the benchmark LTV equation into the baseline model, we will examine whether the hypothesis can be supported by the *risk-taking model*. In this model, banks reset the level of the LTV ratio in every period on the basis of the rule expressed in equation (3.20), that is, based on short-term interest rates and house prices in the previous period.

$$\hat{m}_t = \gamma_1\, \hat{m}_{t-1} \;+\; \gamma_2\, \hat{R}_{t-1} \;+\; \gamma_3\, \widehat{q}_{t-1} \;+\; \hat{e}_t \tag{3.20}$$

where $\hat{m}$, $\hat{R}$ and *hatq* refer to the deviation of the LTV ratio, interest rates and house prices, respectively, from their steady states. $\epsilon_t$ refers to an exogenous shock to the decision process.[23] Low interest rates in the previous period drive them to take more risk for the reasons state previoiusly. To reiterate, these reasons include higher yields from collateralized lending than bonds, underestimation of downside risk to house prices, expectations of robustness in future house prices, and a belief in the 'too big to fail' myth.

Table 3.6 lists the parameter values of the LTV decision rule above. The values are based on the results from the estimation of the regression equation (3.3).

**Table 3.5. Parameter Values for Backward-looking LTV Decision Rule**

| | $\gamma_1$ | $\gamma_2$ | $\gamma_3$ |
|---|---|---|---|
| Value for Calibration | 0.7 | -3.2 | 0.3 |

Figure 3.9 shows the impulse responses to an unexpected decrease in policy rates by 0.5%p. The solid line depicts the results from the *risk-taking model* while the dashed line illustrates the same impulse responses from the baseline model as in Figure 3.7. It is evident that the traditional *interest rate* and *house price* channels in the *risk-taking model* generate similar positive responses of the variables of interest as the baseline model does. However, the *risk-taking channel* pushes up consumption to a higher level during the first year. Specifically, in the *risk-taking model*, the expansionary monetary policy shock induces consumption to deviate positively by 6.5% from the steady-state whereas it generates an increase of 5.0% in the baseline model. The additional increment in the deviation of consumption results from the increase in borrowers' debt. As suggested by our previous discussion about the *risk-taking*

[23] In the model, banks are assumed to deposit and lend funds at the same interest rate and not to impose any transaction cost. For the purpose of simplification, savers are assumed to act as lenders and banks at once.

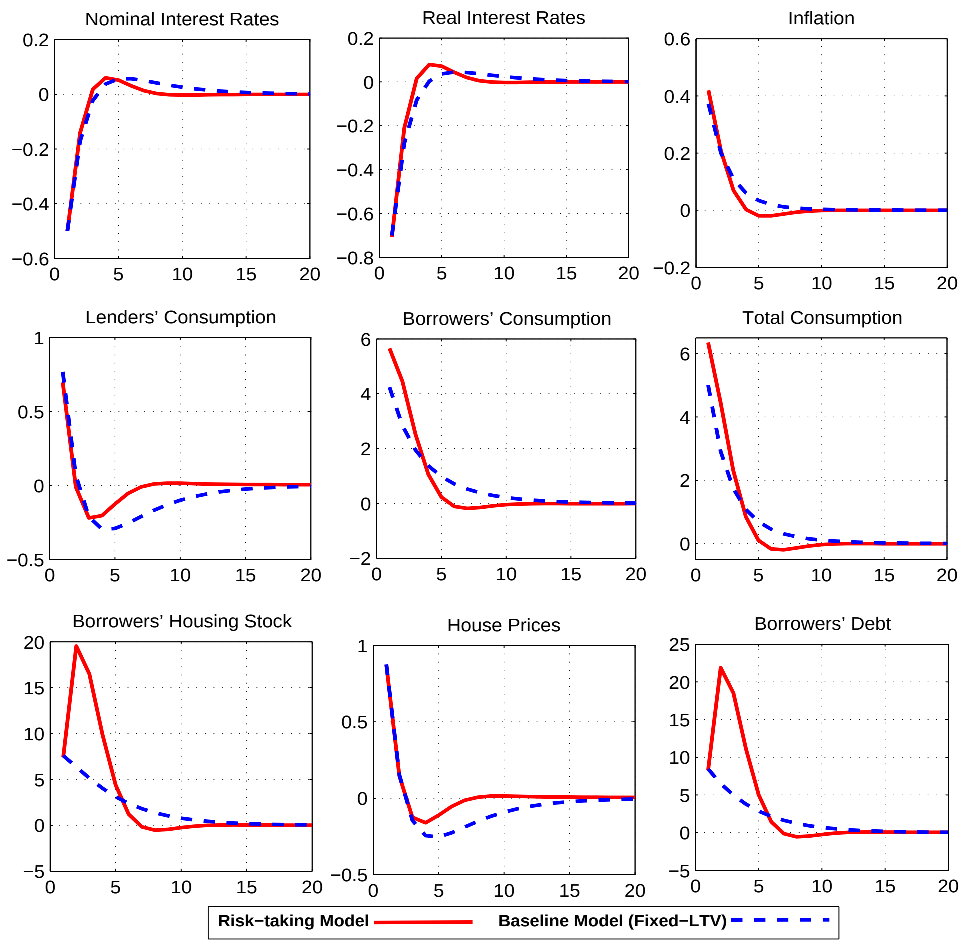
*channel*, lower interest rates lead lenders to forecast higher house prices in the future and consequently to under-estimate the risk of collateralized lending. Lenders are now willing to provide more funds even if there is no change in the collateral value or income level of borrowers.

The difference in the paths of the economy generated by the baseline model and the *risk-taking model* sheds some light on why central bankers failed to forecast the full effects of the long-lasting accommodative policy on the economy. The two traditional channels, i.e., interest rate and collateral channels, might be taken into account in the estimation of the future path of the economy. However, missing the causal chain between low policy rates and bankers' lending behaviour might lead policy makers to underestimate the influence of their decision to maintain low interest rates for a prolonged period in the first half of the last decade.

To continue our discussion, two peculiar features of the impulse responses of house prices and borrowers' debt are noted below.

Firstly, comparing the impulse responses, there exists no difference in the two paths of house prices over the first four quarters. This indicates that the impact of the *risk-taking channel* on consumption results mainly from the decline in policy rates and a subsequent increase in debt rather than the increase in house prices in the first four quarters. In a sense, this is at odds with the hypothesis of the *risk-taking channel*. In the hypothetical economy, lenders adjust their risk-taking attitude by responding to changes not only in policy rates but also in house prices. Fluctuations in house prices send strong signals to mortgage lenders about how risky collateral will be in the future. The *risk-taking model* presented here fails to reflect the causal chain running from realized house prices to lenders' risk-taking attitude in the first four quarters. However, house prices do increase sharply after the first year in the risk taking model. This shows that it takes a while for the risk taking channel to have its full impacts; nevertheless eventually house prices do increase much more with the risk taking channel. This is not inconsistent with observations during the recent housing boom.

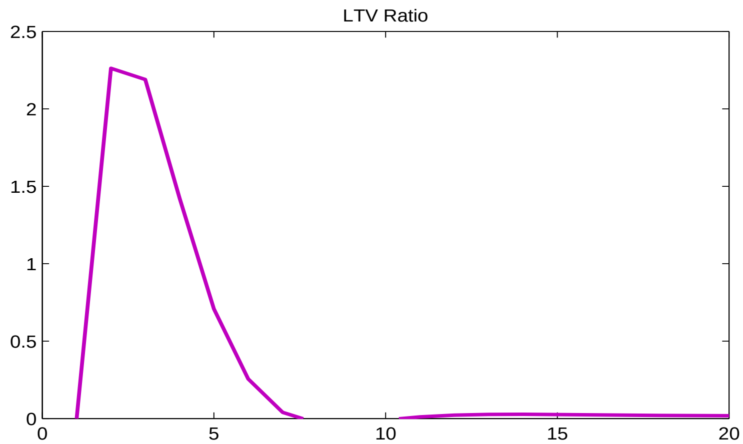
**Figure 3.9. Impulse Responses to a Monetary Policy Shock**




Note: The $y$-axis measures percent deviation from the steady state.

Secondly, the impulse response of borrowers' debt shows no response in the first period and then a rapid upturn in the second period. This result arises from the assumption that lenders decide their LTV ratio on the basis of interest rates and house prices in the previous quarter. As seen from Figure 3.10, the impulse response of the ratio reveals an unnatural kink possibly because of the backward-looking behaviour of lenders. Under this backward-looking decision rule, the response of borrowers' debt to policy change appears to have a more volatile path than the other economic variables. To overcome these shortcomings, an alternative rule is introduced below.

**Figure 3.10. Impulse Response of LTV Ratio**




Note: The $y$-axis measures percent deviation from the steady state.

#### 3.6.1.2 Forward-looking LTV Ratio Decision Rule

To make the assumption on the behaviour of lenders more consistent with reality, a forward-looking decision rule of LTV ratio is introduced below. Lenders adjust the LTV ratio on the basis of the observed level of policy rates and house prices in the current period and also their own expectations of the evolution of these two variables in the next period. Another distinction from the backward-looking rule is the absence of the lagged LTV ratio itself. The omission of the term implies that gradualness in adjusting the LTV ratio is not in the lenders' interest *per se*.

$$\hat{m}_t = \xi_1 \, \hat{R}_t \; + \; \xi_2 \, \widehat{q}_t \; + \; \zeta_1 \, E_t(\hat{R}_{t+1}) \; + \; \zeta_2 \, E_t(\widehat{q}_{t+1}) \; + \; \hat{e}_t \tag{3.21}$$

The parameter values in the forward-looking decision rule are obtained by a regression using the same data used in estimating the backward-looking equation. The responsiveness to the contemporary policy rate is lower than that of the backward-looking rule. The forward-looking coefficient, i.e., $\zeta_1$ is still lower. This result makes sense in that lenders put less weight on their own expectation of policy rates because of the uncertainty inherent in forecasting.

**Table 3.6. Parameter Values for Forward-looking LTV Decision Rule**

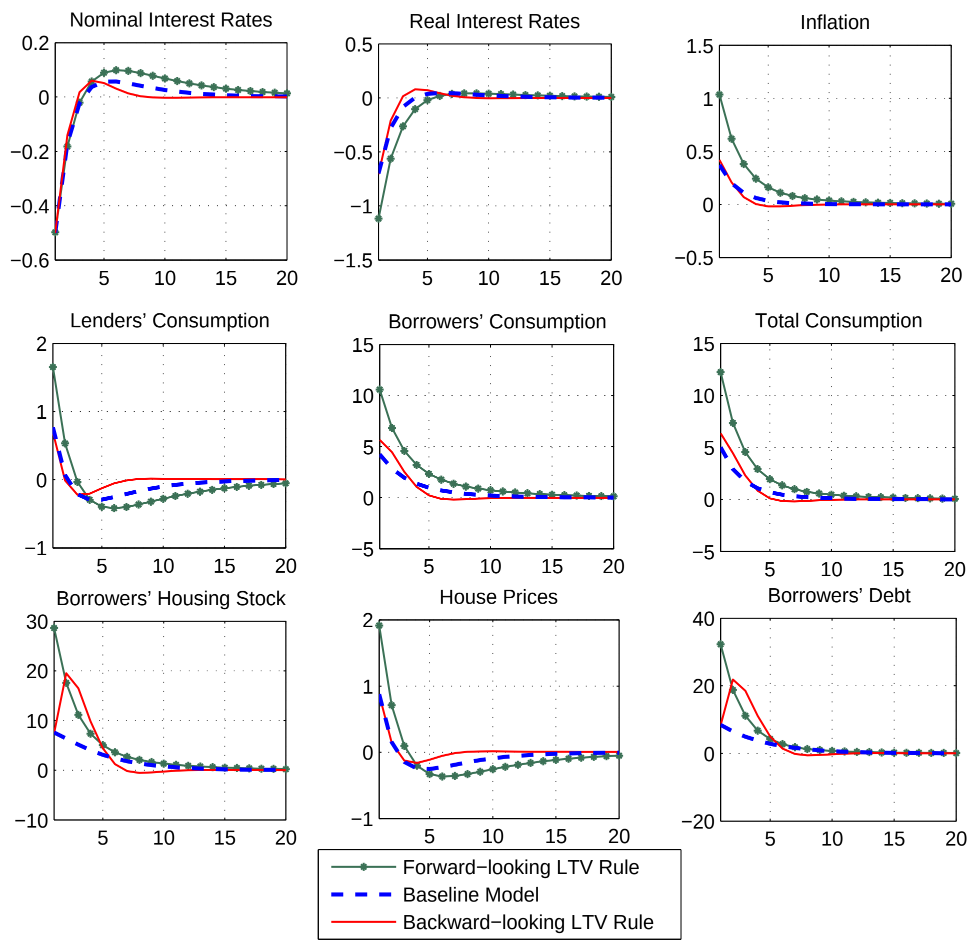
| | $\xi_1$ | $\xi_2$ | $\zeta_1$ | $\zeta_2$ |
|---|---|---|---|---|
| Value for Calibration | -1.95 | 0.21 | -1.77 | 0.16 |

The impulse responses to a shock to monetary policy with a 50bp decrease are illustrated in Figure 3.11. As anticipated, the two *risk-taking* models with a backward-looking rule and forward-looking rule generate more volatile paths of the economic variables than the baseline model. However, even though the two *risk-taking* models share the common characteristics of the *risk-taking channel*, the overall economy displays enhanced deviations in the case of the forward-looking rule. In other words, a monetary policy shock is amplified more when lenders adjust their LTV ratio depending on their forecasts for policy rates and house prices rather than on past information on these variables.

House prices, in particular, show a further deviation from the steady state. As lenders expect future policy rates and housing prices will move and they use these expectations when deciding the LTV ratio for every period, they supply more credit to borrowers. If lenders employed only the information in the previous period, their willingness to make loans might be less than it would otherwise. As a result of more mortgage supply, borrowers can consume more housing and non-residential goods. House prices and consumption display more fluctuations. As such, the model employing the forward-looking LTV decision rule overcomes the shortcomings of the model with the backward-looking rule.

This result provides a forceful insight into the role of the expectations of credit suppliers in the housing market. In retrospect, it is acknowledged that the housing bubble in the run-up to the sub-prime crisis could not have developed only due to the irrational and myopic expectations of housing buyers. One of the main driving forces in the housing market at that time was the infinitely elastic credit supply in response to the demand for loans. Regarding the behaviour of bankers, some researchers have raised the possibility that bankers at that time were as irrational as home buyers in forming their expectations of future housing market situation. The impulse responses generated by the model with the forward-looking rule supports this hypothesis. If lenders draw on their own expectations in deciding the LTV ratio instead of using the realized value of policy rates and housing prices, the economy shows a more volatile path than it would otherwise.

**Figure 3.11. Impulse Responses by Forward-looking LTV Decision Rule**

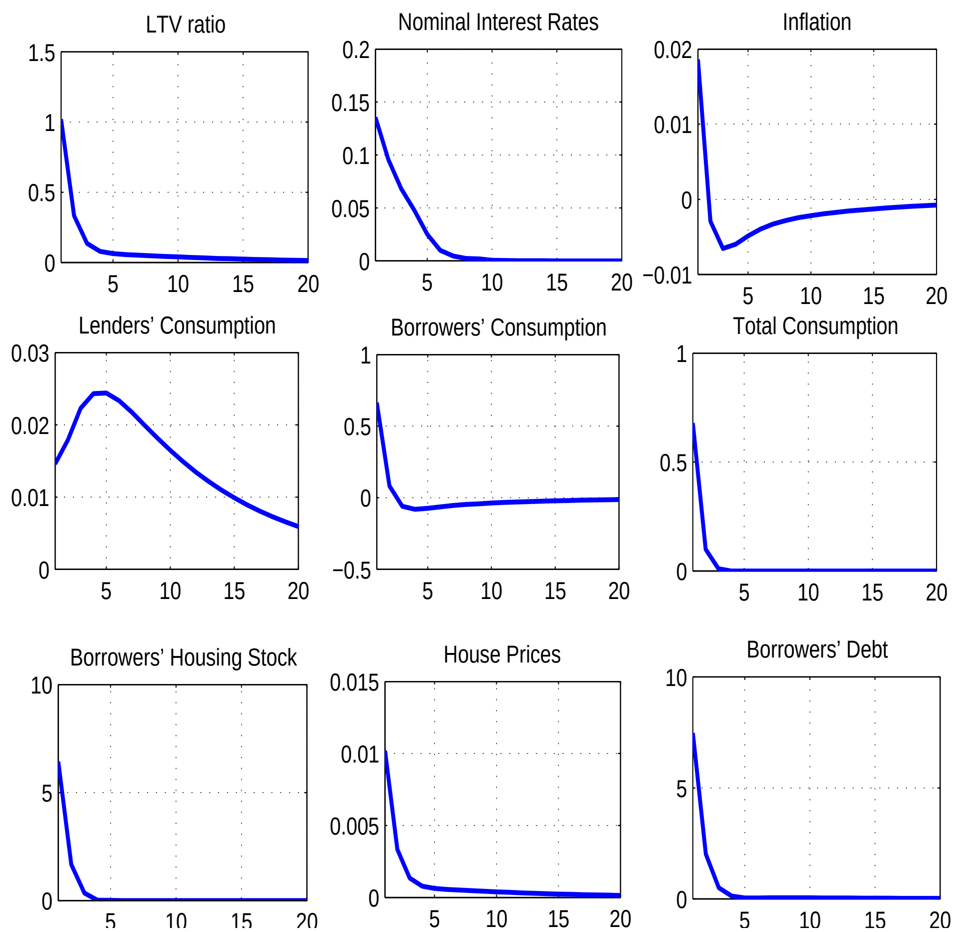



Note: The $y$-axis measures percent deviation from the steady state.

### 3.6.2 LTV shock

We now turn to what happens to the whole economy if a shock to LTV ratio decision process arrives using the forward-looking decision rule introduced above. The shock to the decision process can be a wider latitude to adjust downpayment or change the ceiling on the LTV ratio which are caused by changes in banking regulations. In the context of risk-taking attitude of lenders, the shock can be interpreted as changes in the preference for the risk related to housing-collateralized lending which can be caused, for example, by lenders' optimistic expectation about future house prices and economic activities.

**Figure 3.12. Impulse Responses to an LTV Shock**




Note: The $y$-axis measures percent deviation from the steady state.

Figure 3.12 shows the impulse responses to a positive shock to the LTV decision process which has the magnitude of one percent deviation from the steady-state the LTV ratio. The positive shock implies that lenders become more aggressive in expanding housing-collateralized loans. After the shock hits the economy, lenders supply more credit given a specific level of housing value and borrowers can increase debt not only for consumption but also for house purchases. As the first panel in the same figure reveals, the shock increases the LTV ratio instantaneously by one percent from the baseline, which implies heightened credit availability and leads to a corresponding increase in borrowers' debt. The impulse responses of consumption and house prices are in line with expectation: total consumption increases by 0.8% and house prices rise further 0.05%. The central bank reacts to these output and inflation gaps by increasing policy rates. However, since the gaps are narrow enough to be bridged by a soft response, the magnitude of rate hike is not substantial.

As noted above, an LTV shock exerts only limited influence on the variables compared with a monetary policy shock. The extent to which the variables deviate from the steady state in the presence of an LTV shock are quite smaller than when a monetary policy shock hits the economy. For example, borrowers' consumption deviates by only 0.6% in response to an LTV shock whereas a monetary policy shock causes it to deviate by almost 6% as shown by Figure 3.11. Similarly, the response of housing prices to an LTV shock is less than with a monetary policy shock; house prices change by only 0.01% with the LTV shock whereas they deviate by 2% in reaction to a monetary shock. These differences can be explained by the difference in the channels through which these two shocks are transmitted. As elaborated above, monetary policy is transmitted through three channels: the interest rate channel, house price channel and risk-taking channel. These channels have a long-lasting effect on the economy. On the other hand, an LTV shock directly affects only the amount of lending by patient households to borrowers. Only a 1% deviation of the LTV ratio falls short of exerting strong impact on the behaviour of economic variables, which is consistent with the reality.

However, the qualitative property of the simulated paths of consumption and house prices are consistent with what we observed in certain developed countries during the period before the sub-prime crisis. Mortgage lenders enhanced the LTV ratio to 100 percent, in some extreme cases, even up to 120 percent, and consequently existing home owners could withdraw more equity from their houses. The funds borrowed against housing as collateral were spent in purchasing houses and consuming other goods. The increased demand for housing pushed house prices to an unsustainable level. The loop reiterated itself until mortgage related assets, such as mortgage-backed securities (MBS), turned non-performing as a result of the housing market crash and the functioning of the whole banking sector was then crippled.

## 3.7 Conclusion

The motivation for the analysis originates from the following queries: (i) Why did central banks and most macroeconomists fail to forecast the rapid economic downturn after the sub-prime crisis? (ii) How did the prolonged period of low interest rates affect banks' mortgage supply? (iii) Does there exist any unidentified relationship between the accommodative monetary policy maintained for a protracted period and the devastating aftermath of the financial crisis?

To answer these questions, a micro-founded model is developed which incorporates the hypothesized *risk-taking channel* of monetary policy into a workhorse DSGE model featuring housing-collateralized lending and a borrowing constraint. In the model, lenders become increasingly aggressive towards risk by increasing the LTV ratio as a reaction to a decrease in policy rates. There are two prominent reasons for lenders assuming more risk. These include *search for yield* and the tendency to under-estimate risk in housing-collateralized lending in the presence of robust growth in collateral value. The specific procedure for setting up a DSGE model which mobilizes the *risk-taking channel* underwent two steps. First, two kinds of empirical analysis were conducted using U.S. data during the period from 1980 to 2007: (i) a set of simple regressions with the LTV ratio as the dependent variable and (ii) a VAR model with short-term interest rates, the LTV ratio, and house prices as endogenous variables. In turn, the estimated regression equation chosen as a benchmark equation merges into the baseline model to make the *risk-taking channel* operative. The overarching aim of the *risk-taking model* is investigating whether the *risk-taking channel* amplifies an expansionary monetary policy shock. Additionally, the model enables us to see how the economy behaves in response to a shock to the LTV decision process.

The analysis of impulse responses generated by the *risk-taking model* confirms the hypothesis that with the *risk-taking channel*, the trajectories of consumption and mortgage debt in the model become more volatile. If the *risk-taking channel* operates, an initial monetary policy shock produces more significant deviations of consumption and borrowers' debt from the steady state relative to the baseline model. In particular, if lenders decide the LTV ratio using their own expectations about the future paths of policy rates and house prices, the *risk-taking channel* turns out to have a greater effect on the economy as a whole.

From the analysis, we can derive several implications for monetary policy implementation and financial regulation. First and foremost, to evaluate accurately the influence of monetary policy decisions on economic and financial activities, we need to take into account the impact generated through the *risk-taking channel* in addition to the impact from the traditional transmission channels. If the effects are not given proper consideration, accommodative monetary policy decisions can instead destabilise the whole economy since the response of banks and households to the easy stance will be underestimated. Secondly, regulations on the LTV ratio can contribute to the stability of the economy by curbing the aggressive risk-taking behaviour at the credit supply side. If the *risk-taking channel* is operating, counter-cyclical regulatory interventions in the lending market (by imposing a lower ceiling on the LTV ratio) can smooth the paths of financial and real economic variables alike.

For future research, two points are worth mentioning. To capture the whole picture of the influence on house prices and the whole economy, we need to consider the *risk-taking channel* on the credit demand side in the mortgage market. Secondly, the process of expectation formation still remain a "black box" in evaluating, both empirically and theoretically, the effects of monetary policy decisions on the housing sector. Hence we need to invest more of our resources in identifying and estimating the effects produced via the expectation channel.

# Chapter 4

# Monetary Policy and Credit-driven Volatilities

## 4.1 Introduction

Two main reflections on monetary policy analysis and its implementation have captured the interest of central bankers and academics since the sub-prime crisis broke out. Firstly, the transmission channels of monetary policy were not fully identified and this failure led to underestimation of the actual impact of policy decisions on the housing market and overall economy. Secondly, the failure has arguably been accountable for bringing about the ongoing Great Recession to some extent. With hindsight, if the Federal Reserve (Fed) had forecasted accurately the negative repercussions of its accommodative stance on the economy during 2002-2006, it might have chosen a different path for policy rates.

The first reflection has led a group of researchers to explore transmission channels previously ignored in monetary policy analysis. In particular, a policy transmission route dubbed the *risk-taking channel* has received increasing attention as an additional link between monetary policy and bank lending. Although the theory for this channel is in its early stage at present, recent empirical findings lend firm support to its existence with respect to bank lending standards and risk position (Jiménez *et al*, 2008; Altunbas *et al*, 2010; Delis and Kouretas, 2011, Maddaloni and Peydró, 2011).[1] Chapter 3 applies the *risk-taking channel* to mortgage lending and finds that the loan-to-value (LTV) ratio in the U.S. tends to rise as short-term interest rates decrease. Furthermore, the chapter integrates the transmission channel into a DSGE (Dynamic Stochastic General Equilibrium) framework to investigate the inter-relationship between monetary policy, mortgage lending, housing prices and consumption. These findings imply in tandem that lower policy rates resulted in expansion of the credit lines by encouraging banks to take risk to an excessive extent and, as a consequence, the surfeit of credit fueled the housing boom and robust economic activities prior to the crisis.

In conjunction with the first reflection, a separate policy issue has drawn attention. That is whether, in the run-up to the crisis, adherence to the *conventional strategy* of waiting until the housing boom dissipates was appropriate from the viewpoint of macroeconomic stability.[2] The conventional stance was based on the academic findings of Bernanke and Gertler (1999, 2001) who maintain that the intervention of monetary policy in asset markets may not be effective for smoothing asset prices and can instead be detrimental to the whole economy. Even though critics outside central banks voiced opposition to this argument as in Ceccheti *et al* (2000), it remained only a suggestion and fell short of affecting the actual implementation of monetary policy. However, as the impact of the housing bubble turned out to be more harmful than previously estimated and the financial sector arguably played an important role in the evolution of the crisis, the issue has received renewed interest in light of the interaction between the housing market and macro-financial stability. The sceptics disagreeing with the conventional stance argue that the conventional strategy, which focuses only on output and inflation gaps, can cause economic instability if the influence of the housing sector on the wider economy is underestimated.

[1] A short summary of these empirical findings is provided in Chapter 2.

[2] Kohn (2006) uses the phrase *conventional strategy* to refer to the implicitly orthodox stance of the Fed on asset market fluctuations which is to wait until the asset market bubble bursts and then respond immediately to minimize the negative repercussions of declining asset prices on the real sectors of the economy. See also Greenspan (1999).

For instance, Pariés and Notarpietro (2008), using a DSGE framework find that shocks to the housing sector both in the U.S and Euro area influence non-residential consumption significantly through the collateral channel and a monetary policy rule reacting to house prices improves social welfare. The simulation results in Kannan *et al* (2009) have a similar implication for monetary policy implementation that policy intervention can be a means to minimize negative repercussions from the housing sector on the economy. Their model shows a shock to housing-collateralized lending rates, that varies depending on policy rates, causes overall economic instability; an alternative monetary policy rule reacting to credit is more effective for decreasing undesirable macroeconomic volatilities relative to the standard Taylor rule. Lambertini *et al* (2011) presents a similar conclusion; a policy rule only aiming to stabilize inflation is sub-optimal.[3]

This chapter, as an extension of attempts to accommodate these reflections, aims to demonstrate that (i) an expansionary monetary policy shock intensifies *credit-driven* volatilities through two additional transmission channels and (ii) an alternative policy rule, which responds to credit growth as well as output and inflation gaps, enhances macroeconomic stability.

The two transmission channels incorporated into a DSGE framework are the *preference channel* and *risk-taking channel*. Monetary policy rates affect the preference for housing through the *preference channel*. As regards the *preference channel*, there are various reasons for assuming a link between policy rates and the preference for housing. Firstly, if the user cost of housing becomes cheaper as interest rates decrease, potential home buyers facing credit constraint regard the purchase of housing as more attractive than consumption of non-residential goods. Although there is no literature on the link between the preference for housing and the user cost, Orgaki and Reinhart (1998) can be employed to support the above argument. Based on the relationship between the user cost of durable goods and the marginal

[3] Erceg and Levin (2006) presented simulation results showing that interest rates affect the durable goods sector more than nondurables sector, and a policy rule aimed only at stabilizing changes in the price of final goods rarely improves social welfare.

rate of substitution (MRS) between durables and nondurables derived from the Euler equation of consumer utility maximization, the paper notes that changes in MRS depend on interest rate levels. It argues that interest rates need to be taken into account to prevent a bias in the estimation of the MRS. Secondly, during the boom period of the housing market, psychological factors heavily influence the preference for housing. Case and Shiller (1988), using responses obtained from a questionnaire survey, report that home buyers determine the price they are willing to pay based mainly on their expectation of future housing prices. Expectation of future capital gains can make people move away from non-residential goods to buy housing. In addition, Case and Shiller (2003) note that first-time home buyers are anxious about being priced out of the housing market during a period of continued house price appreciation. The anxiety leads to placing more emphasis on housing relative to other consumption goods. Taking into account the causality chain running from low interest rates to a housing boom and subsequently to psychological aspects, a change in monetary policy rates is an important catalyst for shifting the preference towards housing. Incorporating the *preference channel*, in other words, endogenizing the link between monetary policy and housing preference, is fairly exploratory in that there exists, to the best of my knowledge, no similar attempt not only in models featuring housing but also in other macroeconomic models. However, this experiment can be considered as a necessary intermediate step to overcome the shortcomings caused by the assumption that preferences are simply an exogenous process in studies on housing, as in Iacoviello and Neri (2010).[4]

Through the *risk-taking* channel, monetary policy influences banks' perception of risk related to housing-collateralized lending. As housing is used as collateral, if lower interest rates induce housing prices to appreciate, lenders are more likely to estimate downwards the default risk and the resultant loss. The low risk-perception encourages them to take more risk in lending by raising the LTV ratio. [5]

[4] These shortcomings are set out in Section 4.2.

[5] Chapter 3 provides a more detailed explanation about how monetary policy decisions are transmitted to mortgage lending through the *risk-taking channel*.

With an expansionary monetary policy shock, the model incorporating these two additional channels produces larger volatilities which are driven mainly by the rapid expansion of credit. The two channels mentioned above work at the heart of the transmission mechanism in the model economy. As the demand for housing increases by the preference shifting towards housing through the *preference channel* and borrowing capacity increases by a hike in the LTV ratio through the *risk-taking channel*, the creditlines are increased further *vis*-à-*vis* the case where such channels do not exist. In turn, the buildup in credit fuels the housing market and consumption of goods from other sectors, and finances entrepreneurial investments. As such, the economic scenario presumed by the model describes the circumstances preceding the sub-prime crisis in which bankers took excessive risk and households displayed an overheated demand for housing.

The second aim of this chapter lies in exploring an optimal monetary policy which can best react to *credit-driven* volatilities in terms of welfare maximization. On the premise that the central bank minimizes the loss defined as the weighted average of variances of output and inflation gaps, the performance of alternative policy rules are compared. Among the candidate rules, a policy rule which also allows for the volatility of credit performs best compared with all the other rules including the standard Taylor rule.

The remainder of this chapter is organized as follows. Section 4.2 provides rationales and empirical evidence for the *preference channel* and the *risk-taking channel*. Section 4.3 describes the model and Section 4.4 presents an analysis of the impulse responses to an expansionary monetary policy shock. Section 4.5 compares the performance of different monetary policy rules. The last section sets out my concluding remarks.

## 4.2 Rationale and Empirical Evidence for Endogenizing Housing Preference and LTV Ratio

To achieve the aims of this chapter, a DSGE model will be developed endogenizing the preference for housing and the LTV ratio to reflect the impact of monetary policy decisions through the *preference channel* and *risk-taking channel*. The incorporation of these two channels differentiates the model from a workhorse model featuring the housing market and credit constraint in similar strands of research. In the following subsections, the rationale for the endogenization is demonstrated using empirical evidence obtained from VAR and simple regression methods.

### 4.2.1 Rationale for Endogenizing Housing Preference and LTV Ratio

The DSGE model to be developed borrows its basic framework from Iacoviello (2005) which has been the workhorse DSGE model for analyzing the role of the financial constraints and housing market for the whole economy (Pariés and Notarpietro, 2008; Gerali *et al*, 2010; Lambertini *et al*, 2011). Despite its popularity, it appears to fall short of capturing significant aspects of housing market dynamism. Particularly, it assumes the variables which affect the demand for housing and borrowing of credit-constrained agents as fixed or exogenously determined. These variables include the *preference for housing* in the utility function of households and the *LTV ratio* in the borrowing constraint. The housing preference represents households' subjective appetite for housing. In the common type of utility function, it measures the weight of economic agents assigned to housing relative to non-residential consumption goods. A rise in the weight assigned to housing leads to a hike in the demand for housing and induces agents to borrow more funds from financial intermediaries and, as a resutl, house price appreciation follows. The LTV ratio, on the other hand, affects the affordability of housing since it determines the maximum amount of borrowing against housing as collateral even if income levels and housing values remain constant. This ratio plays an essential role in generating the collateral channel effects in the monetary policy transmission (Kiyotaki and Moore, 1997; Iacoviello, 2005).

However, the relationship between monetary policy decisions and these two variables has been neglected in the workhorse model by assuming that the preference for housing simply follows an exogenous AR(1) process and the LTV ratio is fixed at its long-term average. This assumption fails to capture the full impact of monetary policy transmission on the economy through the housing market and financial sector and hence has the following shortcomings. Firstly, the disconnect between monetary policy and the two variables in the existing model may subdue the impulse responses of financial variables and housing prices to changes in policy rates. The failure in identifying the transmission mechanism results in underestimation of the first-round effects of monetary policy decisions on the supply of credit and the evolution of housing prices. Moreover, it may lead to downplaying the spillover effect of the developments in the housing market on the overall economy. Secondly, if house price volatility is driven purely by an exogenous shock, this is not very helpful in understanding the root causes behind the boom-bust cycle of the housing market. Amazingly, a housing preference shock explains as much as 27% of the variance in the housing prices of the U.S. at business cycle frequencies in Iacoviello and Neri (2010). That finding renders the housing preference shock as integral to the analysis of the U.S. housing market fluctuations. However, the reasons for the preferences shifting towards housing still remains unclear.[6]

A question naturally arises in relation to the above reasoning whether the influence of monetary policy on the preference for housing and the LTV ratio can be corroborated by sound empirical findings and which factors change the preference.

To begin with the *preference channel*, there seems to be no finding supporting the existence of it. Even the previously cited papers having a model featuring the housing sector pay scarce attention probing into an understanding and empirical testing about the determinants of housing preference. However, under the assumption that the preference follows an AR(1) process, Iacoviello (2005) and Iacoviello and Neri (2010) suggest the following factors as possible reasons for its movement: (i) changes in the availability of funds to buy housing relative to other goods, (ii) positive expectation of future house-price movements.[7]

[6] In Iacoviello and Neri (2010), an example of a shock to preference for housing includes a tax benefit applied to home buyers. However, in the past empirical evidence on the determinants of house price volatilities, a tax treatment exerts fairly limited influence on the demand for housing.

[7] Temporary tax benefit can be another shifter of housing preference. However, its influence is limited to a specific group of home buyers rather than pervasive.

The first and second factors correspond to the user cost of housing and psychological factors, respectively, which were elaborated on in Chapter 2. A further question arises about what causes the changes in the available funds needed for the purchase of housing and optimistic expectations. Firstly, as Himmelberg *et al* (2005) notes, interest rates are a crucial determinant of the user cost of housing. This can be explained by consideration of the determinants of user cost.[8] Below is the primitive form of the equation for the user cost of housing which is formulated in Poterba (1984).

$$w = [(1-\theta)(i+\tau_p) + \delta + p - q_g] \tag{4.1}$$

where $\theta$ denotes a marginal tax rate for the ownership of housing, $i$ is mortgage interest payment, $\tau_p$ is property taxes, $\delta$ is after-tax depreciation, $p$ is repair cost and $q_g$ is capital gain on housing.[9] In equation (4.1), the interest rate directly influences the mortgage interest payments in the function. Additionally, it affects another argument of the house price appreciation $q_g$ in the user cost since interest rates have been found to affect housing prices negatively to a substantial degree in normal circumstances.[10] These direct and indirect effects make interest rates the most influential determinant of the user cost of housing. Secondly, interest rates also influence psychological anticipation of future housing prices due to the common sense belief that lower interest rates result in housing price inflation. Case and Shiller (1988) provide evidence that changes in interest rates are the most common answers to the survey question asking what ignites a housing boom. This means that low interest rates are more

[8] In the context of durable goods, empirical findings confirm the significant role of interest rates for expenditure on durable goods through their influence on the user cost, as shown by Hamburger (1967), Mishkin (1976), Mankiw (1985), Erceg and Levin (2006).

[9] The interest rate can be nominal or real. There was a heated debate in the late 1970s and early 1980s following the Great Inflation as to whether nominal or real interest rates were relevant for housing prices; real or nominal. However, since then the difference has been considered peripheral and nominal interest rates have been used as an explanatory variable in empirical studies. In addition, the interest rate can be short-term or long-term. Since there seems to be a stable term structure between the two kinds of interest rates as Chapter 2 clarifies in the case of the U.S., this distinction appears to be irrelevant for our analysis.

[10] Several empirical findings lend firm support to the conclusion that interest rates are the main driver of house price fluctuations. Examples are Meen (2002), OECD (2004), Hofman *et al* (2005), Oikarinen (2005), Iossifov *et al* (2008).

likely to instill optimism in the participants in the housing market under normal conditions.[11]

All in all, interest rates as an instrument of monetary policy affect the housing preference directly through the user cost of housing and indirectly through expectations.[12] The *preference channel* can be decomposed into two separate channels; the *user cost channel* and *expectation channel* as illustrated below.[13]

■ User Cost Channel

- $R \downarrow \longrightarrow M \downarrow \longrightarrow J \uparrow$

■ Expectation Channel

- $R \downarrow \longrightarrow q_g^e \uparrow \longrightarrow J \uparrow$

where $R$ denotes monetary policy rates, $M$ is payment of mortgage interest, $J$ is the preference for housing and $q_g^e$ refers to expectations of future capital gain on housing.

A shift in preference towards housing implies an increase in the weight on housing in the standard utility function used in the literature. The generic form of the utility function is given as follows.

$$U(c_t, h_t) = \ln c_t + J_t \ln h_t \tag{4.2}$$

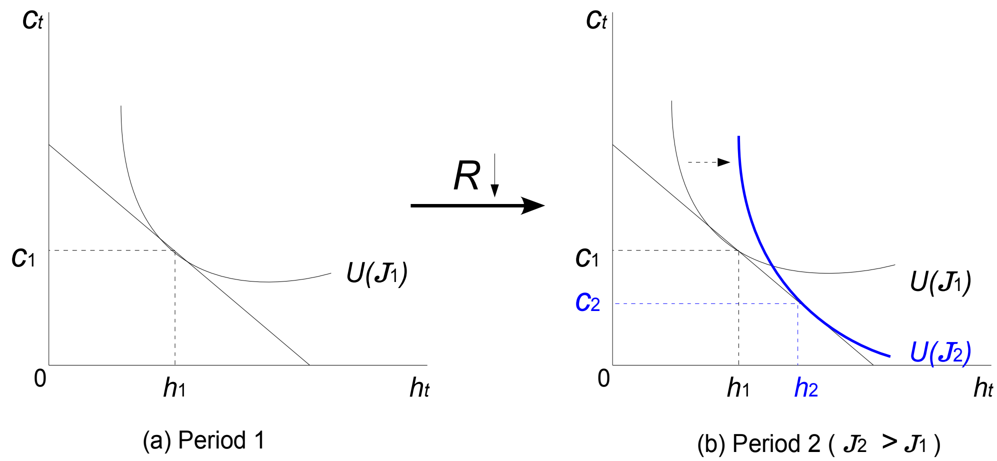
where $c$ and $h$ refer to consumption of non-residential goods and housing stock, respectively, and $J$ denotes housing preference. As both the weight on housing and the marginal rate of substitution between housing and other consumption goods, $J$ reflects the change in the preference for housing and affects the relative allocation of available financial resources. Figure 4.1 illustrates its allocative role through consumers' utility maximization.

[11] The normal conditions include stable income growth, an efficiently functioning financial sector, absence of strong negative shocks to the economy, *et cetera*.

[12] As for durable goods, only the user cost affects the preference of consumers. Monacelli (2009) notes that lower policy rates generate a substitution toward durable goods.

[13] If the realized capital gain on housing $q_g$ in equation (4.1) is replaced by expectations of future capital gain $q_g^e$ as in Mishkin (2007), the expectation channel merges into the user cost channel. However, this specification of the user cost has a shortcoming in that it obfuscates the distinction between these two channels.

**Figure 4.1. Effect of Change in Housing Preference**




In the first period, households maximize their utility with the consumption bundle ($c_1$, $h_1$) and housing preference $J_1$. As interest rates decrease at the beginning of the second period, they regard housing as more attractive since debt financing becomes cheaper and housing prices are expected to rise. Subsequently, the marginal utility of housing increases and hence the slope of the indifference curve $J_2$ becomes steeper than $J_1$. Meanwhile, the level of utility remains the same, i.e. $U(J_1) = U(J_2)$ in the same figure. The stronger preference for housing leads to the new consumption bundle ($c_2$, $h_2$) by allocating more funds to housing given the same budget constraint.

Turning to the *risk-taking channel* in terms of the relationship between monetary policy stance and the LTV ratio, there hardly exists any relevant empirical evidence for the link except the one provided in Chapter 3.[14] In that chapter, both the simple regression and VAR analysis confirm the existence of the negative relationship between the Federal Funds Rate (FFR) and the LTV ratio in the U.S. for the period 1980-2007. That empirical finding implies that mortgage lenders, including commercial banks and housing finance agencies, raise their LTV ratio in response to decreases in FFR. The theoretical basis for this finding is in Rajan

[14] However, recent literature, such as Jimenéz *et al* (2008) *inter alia*, on the relationship between monetary policy stance and risk-taking behaviour of banks reveals that banks are liable to take more risk in lending in a low interest rate environment.

(2006) and Borio and Zhu (2008). In these papers, lower interest rates propel investors and financial intermediaries to tolerate more risk to search for higher yield and perceive downside risks to their investments as lower. This transmission route is dubbed the *risk-taking channel* by Borio and Zhu (2008). In the context of mortgage lending, lenders are prone to evaluate the default risk of borrowers regarding mortgages as lower in the boom phase of a housing market which is bolstered by an accommodative monetary policy stance for an extended period.

### 4.2.2 Empirical Evidence

Empirical evidence for the negative impact of policy rates on the LTV ratio using U.S. data is documented in detail in Chapter 3; here empirical findings from VAR and regression are provided solely for the relationship between monetary policy rates and housing preference only. These two empirical methods require the time series of housing preference. However, since preference for housing is not directly observable, it is indirectly inferred from the optimality condition for households' utility maximization in the workhorse model.

In the simplest form of optimization problem, households maximize lifetime utility by consuming housing and other goods as follows.

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln c_t + J_t \ln h_t\right) \tag{4.3}$$

under the following budget constraint

$$c_t + q_t \left(h_t - h_{t-1}\right) = I_t \tag{4.4}$$

Above, $c_t$ and $h_t$ denote consumption of goods and holding of housing respectively, $J_t$ is a weight on housing relative to other consumer goods. In the budget constraint, $q_t$ refers to housing price and $I_t$ is income. Then Euler equation for this specific optimization program is given as below.

$$\frac{q_t}{c_t} = \frac{J_t}{h_t} + \beta\, E_t\left(\frac{q_{t+1}}{c_{t+1}}\right) \tag{4.5}$$

Assuming perfect foresight and rearranging (4.5) delivers the following definition of housing preference.

$$J_t = \tau\, \frac{q_t\, h_t}{c_t} \tag{4.6}$$

where $\tau$ is a scale parameter equal to $(1-\beta)$. Under the standard assumption about the value of discount factor $\beta$, $\tau$ is approximately 0.01.

In the optimality condition, $J_t$ is defined as the ratio of the value of household residential structure to the total personal consumption expenditure. Following this definition, the time series of housing preference is constructed using U.S. data on the residential structure value in the Flow of Funds and private consumption expenditure in the National Income and Personal Accounts (NIPA).[15]

Using the data, a VAR analysis is conducted to identify the relationship between the Federal Funds Rate (FFR) and the preference for housing through impulse response functions. Monetary policy tightening raises borrowing cost. A higher borrowing cost leads households to diminish the weight on housing which will result in a reduced demand for mortgage loans, leading eventually to house price depreciation. To validate this hypothesis, the following VAR model is estimated using U.S. quarterly data over the sample period 1980 Q1-2006 Q4.

$$\Gamma y_t = c + A(L)\, y_{t-1} + \Sigma e_t \tag{4.7}$$

where $y_t$, a vector of endogenous variables, includes six variables: the Federal Funds Rate ($FFR_t$), the weight on housing $(J_t)$[16] , the change rates of household mortgages ($MOR_t$)

[15] The Flow of Funds and NIPA are published by the Fed and Bureau of Economic Analysis (BEA) respectively.

[16] To ensure the stationarity of the time series of $J_t$, *changes* in the value of the real household residential structure ($q_t\, h_t$) and the real PCE on goods are used instead of the *levels*.

and the real house price index ($HPIG_t$), the percent change of real Personal Consumption Expenditures (PCE) on durable goods ($DUR_t$) and nondurables ($NDUR_t$).[17] Using the notations, $y_t$ can be defined in the following vector form.

$$y_t = [FFR_t,\, J_t,\, MOR_t,\, HPIG_t,\, DUR_t,\, NDUR_t] \tag{4.8}$$

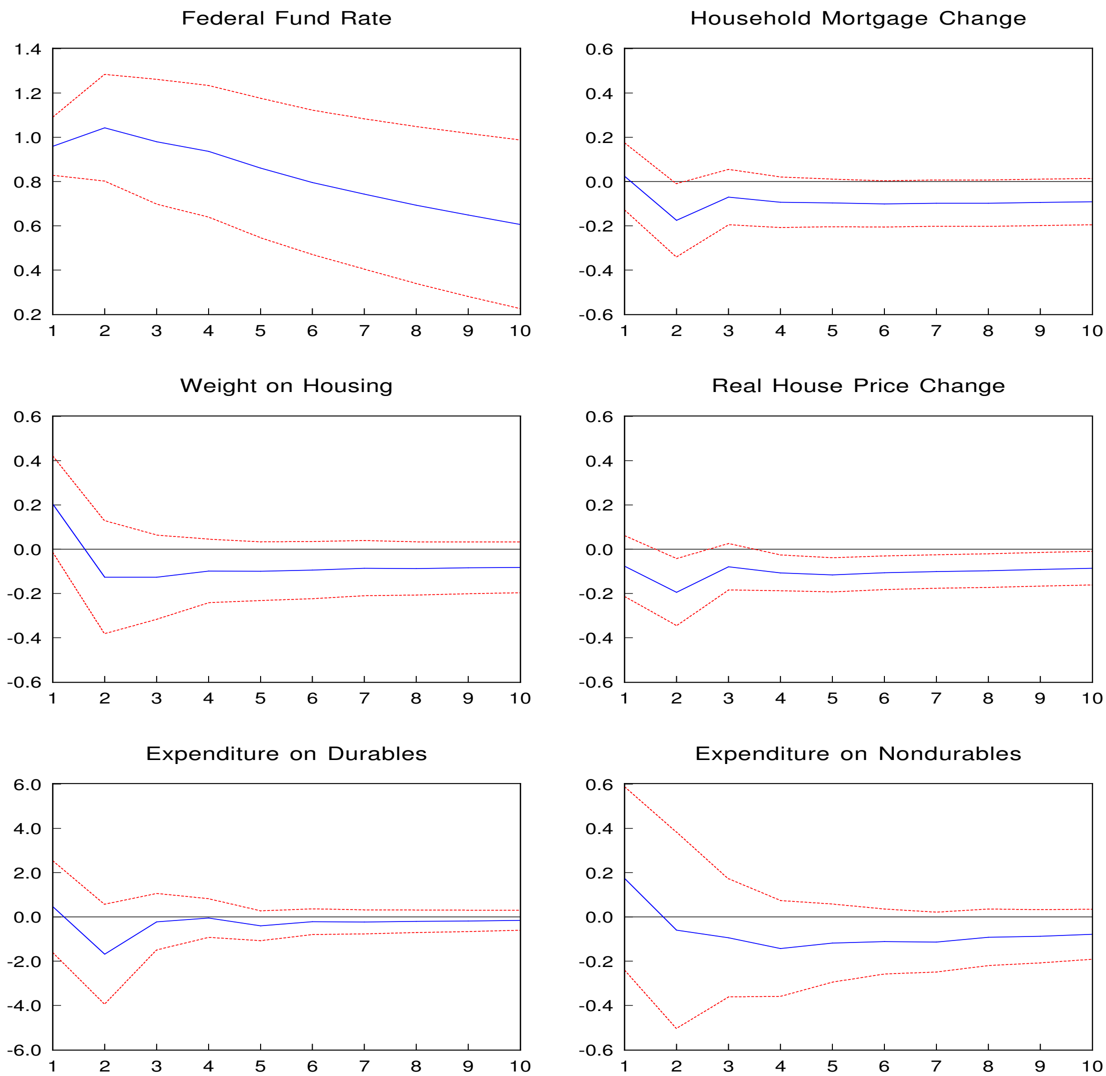
To identify a monetary policy shock, the standard Cholesky decomposition method is employed and the variables are ordered as in the equation (4.8). Figure 4.2 displays the estimated impulse responses of the six endogenous variables to one standard deviation innovation in the Federal Funds Rate. The vertical axis measures *percent changes* of $FFR$ and the weight on housing $J$, and *change rates* for the remaining variables. As shown in the same figure, the weight on housing decreases by 40 basis point during the second quarter following a negative monetary policy shock arrives and this impact persists thereafter.[18] The shock to policy rates causes a spike in lending rates which renders the purchase of housing less attractive than before. As a consequence of the weaker preference for housing, the amount of mortgage loans for buying housing shrinks on the one hand while house prices depreciate on the other hand. Even though existing literature has not allowed for the housing preference explicitly, the result of this impulse response analysis is consistent with past empirical findings about the relationship between interest rates and house prices in which interest rates are negatively associated with housing prices. The contribution of our analysis lies in revealing the additional channel through which interest rates are transmitted to housing prices. In addition, the two panels in the bottom row of Figure 4.2 reveal that monetary policy tightening also negatively affects personal consumption expenditure on both durable and nondurable goods. These findings are consistent with the results of the VAR analysis in Erceg and Levin (2006) and Monacelli (2009).

[17] The data source of $FFR_t$ and $MOR_t$ is the Fed. The real house price index is obtained by deflating the nominal house price index obtained from the Federal Housing Finance Agency (FHFA) by the PCE price index from NIPA.

[18] The strong persistence in the impulse response reflects the inertia in the data on $J_t$.

Overall, the results from the analysis of the impulse responses corroborate the hypothesis that monetary policy rates negatively influence the preference for housing. In addition, the resulting preference shift affects house prices and the demand for mortgages.

**Figure 4.2. Impulse Response to a Negative Monetary Policy Shock**




Note: The dashed line represents two standard error bands.
Data Source: Federal Reserve, Bureau of Economic Analysis, Federal Housing Finance Agency

To reinforce the empirical grounds for the causality running from monetary policy rates to housing preference, a simple regression analysis is conducted regressing the weight on housing

($J_t$) on its one-quarter lag ($J_{t-1}$) and one quarter lagged Federal Funds Rate ($FFR_{t-1}$) over the period 1980 Q1 - 2008 Q4. As the time series of $J_t$ includes a unit root, the Cochrane-Orcutt method is employed to eliminate serial correlation in the error term. The estimated regression equation is as follows:

$$
\begin{aligned}
J_t = 0.4330\, J_{t-1} \, - 0.29\, FFR_{t-1} + \epsilon_t \\
\bar{R}^2 = 0.26 \qquad DW = 1.93
\end{aligned}
\tag{4.9}
$$

where the coefficient of $FFR_{t-1}$ is significant at the 1% significance level. The estimated equation reveals that if the federal funds rate increases by 1%p, the weight on housing decreases by 0.29%p. This result reconfirms the negative relationship between monetary policy rates and housing preference.

Since empirical evidence from both VAR and regression analysis is supportive of the hypothesis that preference for housing reacts negatively to changes in policy rates, this relationship is incorporated into the model developed in the following section.

## 4.3 The Model

The model set out below modifies the framework of Iacoviello (2005) in two dimensions. First, the weight on housing in the utility function of households is endogenized drawing on the empirical findings presented in the previous section. Second, the banking sector plays a role in ensuring a lending market equilibrium by adjusting the LTV ratio to variations in monetary policy rates and house prices.

### 4.3.1 Households

There are two types of households: the patient and the impatient. Impatient households are assumed to value relatively more the utility of the current period than patient ones. On the other hand, patient households are almost indifferent to the timing of consumption and hence are able to save by deferring consumption to subsequent periods. To maximize utility, impatient households have an incentive to borrow funds from banks in which patient households have deposited their savings for consumption and purchase of housing in the future time periods.

A representative household of each type of household maximizes the same form of lifetime utility function as follows.

$$E_0 \sum_{t=0}^{\infty} \beta_p^t \left[ \ln c_{p,t} + J_t \ln h_{p,t} - \frac{(L_{p,t})^{\varphi}}{\varphi} + \chi \ln \left( \frac{M_{p,t}}{P_t} \right) \right] \tag{4.10}$$

$$E_0 \sum_{t=0}^{\infty} \beta_i^t \left[ \ln c_{i,t} + J_t \ln h_{i,t} - \frac{(L_{i,t})^{\varphi}}{\varphi} + \chi \ln \left( \frac{M_{i,t}}{P_t} \right) \right] \tag{4.11}$$

The subscripts $p$ and $i$ denote patient (savers) and impatient (borrowers) households respectively. $c$ is consumption of non-residential goods, $h$ is stock of housing, $L$ is labor hours and $M/P$ refers to real money balance. The parameter $\varphi$ measures aversion to labor supply.

A crucial distinction between these two maximization problems exists in the difference between the discount factors of patient and impatient households. Patient households discount future consumption less than the other type of households, i.e., $\beta_p > \beta_i$. This condition ensures that the borrowing constraint of impatient households binds at a steady state.[19]

$J_t$ denotes the weight on housing relative to non-residential goods which captures the subjective preference for housing. It depends both on economic and non-economic factors that affect the attractiveness of housing. As mentioned in the previous section, policy rates are among the most potent shifters of housing preference. Drawing on this reasoning and the findings from the regression analysis presented above, the law of motion for $J_t$ is defined as below.

$$\ln J_t = (1 - \rho_J)\, \bar{J} + \rho_J \ln J_{t-1} - \gamma_R \ln R_{t-1} + u_{J,t} \tag{4.12}$$

[19] The proof is in Appendix B-1 of Chapter 3.

where $\rho_J$ measures persistence in the preference for housing and $\gamma_R$ is the responsiveness of housing preference to changes in policy rates. $\bar{J}$ is the steady state of $J_t$ and assumed to be 0.12 as in Iacoviello and Neri (2010). $u_{J,t}$ is a shock to housing preference which is independently and identically distributed with variance $\sigma_J^2$. This shock captures relatively less important shifters of housing preference. For instance, they include changes in tax treatment such as a temporary exemption from stamp duty and common perception of the value of home ownership during a certain time period.

Both types of households face budget constraints in solving their utility maximization problems. The main characteristic of the budget constraint of patient households is that they save a portion of their income and deposit the fund ($s_t$) at banks to earn interest income at the (gross) rate $R$. Their utility maximization is subject to the following flow of funds.

$$c_{p,t} + q_t\,(h_{p,t} - h_{p,t-1}) + s_t = w_{p,t}\,L_{p,t} + \frac{R_{t-1}\,s_{t-1}}{\pi_t} + F_t + T_{p,t} - \Delta\left(\frac{M_{p,t}}{P_t}\right) \tag{4.13}$$

where $w$ is real wage and $R$ denotes the interest rate applied to deposited funds. $q$ is real housing price and $\pi$ denotes gross inflation. $F$ is dividends received from retailers and $T$ refers to net transfers from the government.

Impatient households also supply labor to entrepreneurs. However, they borrow funds from banks because they are relatively more impatient. Their flow of fund is as follows.

$$c_{i,t} + q_t\,(h_{i,t} - h_{i,t-1}) + \frac{R_{i,t-1}\,b_{i,t-1}}{\pi_t} = b_{i,t} + w_{i,t}\,L_{i,t} + T_{i,t} - \Delta\left(\frac{M_{i,t}}{P_t}\right) - \xi_{i,t} \tag{4.14}$$

where $R_i$ is the lending rate applied to loans to impatient households which is determined by banks and $b_i$ refers to the funds borrowed from banks. The last term $\xi_{i,t}$ is housing adjustment cost defined as $(\psi_h\,(h_{i,t} - h_{i,t-1})^2\,q_t\,h_{i,t-1})/2$.

An additional constraint is imposed on the maximization problem of impatient households.

This is a borrowing constraint expressed by the inequality below.

$$b_{i,t} \leq m_{i,t}\, E_t \left( \frac{q_{t+1}\, h_{i,t}\, \pi_{t+1}}{R_{i,t}} \right) \tag{4.15}$$

where $m_{i,t}$ is the LTV ratio for bank loans to impatient households. The maximum amount that can be borrowed by impatient households changes with the value of housing as collateral (as in the typical model with a collateral constraint). However, the important distinction here is that the borrowing capacity varies with the LTV ratio which is controlled by banks. Even if real housing prices remain fixed at a certain level, impatient households can increase borrowing if banks increase the LTV ratio.

### 4.3.2 Entrepreneurs

Entrepreneurs produce intermediate goods using the labor of both patient and impatient households ($L_p$, $L_i$), capital ($K$) and housing ($h_e$) as inputs. The production technology is given as below.

$$\begin{aligned} Y_t &= A_t\, K_{t-1}^{\mu}\, h_{e,t-1}^{\nu}\, (L_{p,t})^{\alpha(1-\mu-\nu)}\, (L_{i,t})^{(1-\alpha)(1-\mu-\nu)} \\ A_t &= \rho_A\, A_{t-1} + u_{A,t} \end{aligned} \tag{4.16}$$

Above, $A_t$ represents total factor productivity (TFP) and $u_{A,t}$ is a technology shock with variance $\sigma_A^2$. Entrepreneurs maximize lifetime utility accruing from consumption as follows.

$$\max \;\; E_0 \sum_{t=0}^{\infty} \beta_e^t \ln c_{e,t} \tag{4.17}$$

under the following budget constraint

$$\begin{aligned}\frac{Y_t}{X_t} + b_{e,t} = c_{e,t} + q_t\left(h_{e,t} - h_{e,t-1}\right) + \frac{R_{t-1}b_{e,t-1}}{\pi_t}\\ + I_t + w_{p,t}\,L_{p,t} + w_{i,t}\,L_{i,t}\\ + \frac{\psi_K}{2\delta}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2 K_{t-1} + \frac{\psi_h}{2}\left(\frac{h_{e,t} - h_{e,t-1}}{h_{e,t-1}}\right)^2 q_t\,h_{e,t-1}\end{aligned} \tag{4.18}$$

where $I_t \equiv K_t - (1-\delta)K_{t-1}$ and the last two terms on the righthand side refer to the adjustment costs of capital and housing respectively. Like impatient households, entrepreneurs face the same form of borrowing constraint as equation (4.15).

$$b_{e,t} \leq m_{e,t}\,E_t\left(\frac{q_{t+1}\,h_{e,t}\,\pi_{t+1}}{R_t}\right) \tag{4.19}$$

Analogous to the relationship between the discount factors of patient and impatient households, $\beta_e$ is assumed to be less than $\beta_p$ to ensure that the borrowing constraint binds at a steady state.

### 4.3.3 Banking Sector

The main function of the banking sector is financial intermediation between savers and borrowers.[20] Bankers are only interested in minimizing the possible loss incurred by default on loans collateralized by housing or by legal penalties imposed by the government in the case of a banking failure.

$$E_0\sum_{t=0}^{\infty}\beta_f^t\,LL \tag{4.20}$$

where $LL$ refers to the loss function.

Bankers face the following constraint in this minimization problem:

$$R_{t-1}\,d_{t-1} + l_{i,t} + l_{e,t} = d_t + R_{i,t}\,l_{i,t-1} + R_{e,t}\,l_{e,t-1} \tag{4.21}$$

[20] The banking sector includes all financial intermediaries which supply housing-collateralized lending.

where $d$ is deposits from patient households ($d = s$) and $R$ denotes the deposit rate which appeared in the budget constraint of patient households. The $l_i$ and $l_e$ are loans to impatient households and entrepreneurs respectively and $l_i = b_i$ and $l_e = b_e$. The interest rates $R_i$ and $R_e$ refer to the corresponding lending rates. The constraint can be interpreted as a regulatory stipulation that bankers should clear the lending market at all times.[21]

To simplify the analysis, conversion of deposits to loans is assumed to be costless as in a frictionless model in which deposit rates are equal to lending rates, $R_t = R_{i,t} = R_{e,t}$. As the borrowing constraints of impatient households and entrepreneurs bind at a steady state, $l_{i,t} = (q_{t+1}\, h_{i,t}\, \pi_{t+1})/R_t$ and $l_{e,t} = (q_{t+1}\, h_{e,t}\, \pi_{t+1})/R_{e,t}$. Then the equation (4.21) can be re-expressed using these equalities as follows:

$$\begin{aligned} R_t\, d_{t-1} + m_{i,t}\, E_t \left( \frac{q_{t+1}\, h_{i,t}\, \pi_{t+1}}{R_t} \right) + m_{e,t}\, E_t \left( \frac{q_{t+1}\, h_{e,t}\, \pi_{t+1}}{R_t} \right) \\ = d_t + q_t\, \pi_t\, (m_{i,t-1}\, h_{i,t-1} + m_{e,t-1}\, h_{e,t-1}) \end{aligned} \tag{4.22}$$

To minimize the loss by ensuring the market equilibrium of $d_t = l_{i,t} + l_{e,t}$, bankers adjust the LTV ratio ($m_t$) in every time period based on their judgement of default risk in housing-collateralized lending.[22] Since the default risk is mainly affected by changes in housing value, bankers should forecast housing prices in the next period to decide the LTV ratio. Bankers are assumed to understand that policy rates affect housing prices negatively and that the historical path of housing prices has shown strong inertia. Accordingly, the main indicators they consult in forecasting the future housing value are policy rates and house prices. Under favourable conditions of low policy rates and rising housing prices, bankers forecast the housing value to continue to rise in the following period. This evaluation leads bankers to perceive the default risk of housing-collateralized lending as lower and tolerate more risk by raising the

[21] A possible motivation for market clearance can be a penalty to be imposed in the event of the failure of intermediation.

[22] Bankers in practice determine their risk-taking level mainly from the incentive to maximize aggressively the margin between the rates of deposit and lending under various constraints. However, their decision on risk-taking is assumed to be rather passive to minimize the loss under the simplifying assumption that a unique interest rate $R_t$ prevails.

LTV ratio. Taking into account the time lag between monetary policy and its effects on the housing market, the policy rates in the last period enter their LTV decision rule. Drawing on the findings from empirical analyses in Chapter 3, the LTV decision rule employed by bankers is specified as below.

$$m_t = \rho_m \, m_{t-1} - \phi_R \, R_{t-1} + \phi_q \, q_{t-1} + u_{m,t}, \quad u_{m,t} \sim i.i.d.(0, \sigma_m^2) \tag{4.23}$$

According to this rule, bankers increase their LTV ratio if policy rates decrease or house prices appreciate in the previous period.

### 4.3.4 Price Rigidities and Monetary Policy Rule

The core assumption of price rigidity in the New Keyensian model is briefly explained here.[23] A continuum of retailers of mass unity buy wholesale goods from firms at $P_t^w$ and sell them to consumers at $P_t$. The prices in the consumption sector become rigid as only a fraction 1-$\theta$ of, and not all, retailers under monopolistic competition reoptimize sales price in each period.[24] Under this Calvo-style pricing assumption, the optimization process of retailers delivers New Keyensian Phillips Curve ($NKPC$) as below.

$$\ln \left( \pi_t - \pi_{t-1} \right) = \beta_p \, E_t \ln \pi_{t+1} - \ln \pi_t - \kappa \ln \left( \frac{X_t}{X} \right) \tag{4.24}$$

where $\pi$ is gross inflation, a markup $X_t = P_t / P_t^w$, and $\kappa = \frac{(1-\theta)(1-\beta_p \, \theta)}{\theta}$.

To close the model, a Taylor-type monetary policy rule is assumed as follows:

$$R_t = R_{t-1}^{\rho_R} \left( \pi_{t-1}^{r_\pi} \left( \frac{Y_{t-1}}{Y} \right)^{r_Y} \overline{rr} \right)^{1-\rho_R} \; u_{R,t} \tag{4.25}$$

[23] A more detailed explanation is documented in Chapter 3.

[24] As in Iacoviello and Neri (2010), housing prices are presumed to be relatively more flexible.

where $\overline{rr}$ and $Y$ denote the steady-state real interest rate and output, respectively, and $u_{R,t}$ is an independently and identically distributed monetary policy shock with variance $\sigma_R^2$. The parameter $\rho_R$ is for interest rate smoothing, and $r_\pi$ and $r_Y$ refer to the responsiveness of policy rates to inflation and output respectively.

### 4.3.5 Market Clearing Conditions

The market clearing condition for the housing market is $H_t = h_{p,t} + h_{i,t} + h_{e,t}$ where the housing stock $H_t$ is assumed to be fixed and normalized to 1. The goods market equilibrium condition is satisfied by $Y_t = c_{p,t} + c_{i,t} + c_{e,t} + K_t + (1 - \delta)K_{t-1}$. In order for the lending market to be in equilibrium, $D_t = L_{i,t} + L_{e,t}$. Appendices C-1 and C-2 provide, respectively, the first-order conditions for the optimization problems and the log-linearized system of the model.

## 4.4 Impulse Response Analysis

The main aim of the model is to provide the evidence that a shock to monetary policy decisions generates more pronounced effects through the additional transmission channels discussed previously. This is characterized by two ways: (i) excessive risk-taking by bankers, and (ii) response of the preference for housing to changes in interest rates. These two characteristics were observed during and after the period when policy rates were argued to remain below the Taylor rule prescriptions.[25] Taylor (2007) contended that during the period from 2002 to 2005 there existed a significant deviation of short-term interest rates from the counterfactual level estimated by his eponymous rule.[26] According to Taylor's argument, the model economy is assumed to be hit by an unexpected shock to monetary policy.

[25] The link between low policy rates and excessive risk-taking of financial institutions has been recently found in several empirical findings, e.g. Ioannidou *et al* (2009), Altunbas *et al* (2010), Delis and Kouretas (2011), Maddaloni and Peydró (2011).

[26] As mentioned before, this argument was later rebuffed by the staff at the Fed which includes Bernanke (2010) and Dokko *et al* (2010).

We now provide a list of the parameter values used in the model before an analysis of impulse responses to an unexpected easing of policy stance.[27]

### 4.4.1 Parameter Calibration

Most parameter values are borrowed from Iacoviello (2005) and Iacoviello and Neri (2010) except those in the housing preference equation and LTV decision rule. The parameter values for the law of motion of housing preference $J_t$ are based on the regression results presented in the previous section while the LTV ratio ($m_t$) rule is parameterized using values from Chapter 3. Table 4.1 lists the calibrated values of the parameters. The discount factor of patient households $\beta_p$ is set as 0.9925; this implies a steady state annualized real interest rate of 3 percent. To ensure that the borrowing constraints of impatient households and entrepreneurs bind at a steady state, $\beta_i$ and $\beta_e$ are set lower than $\beta_p$ as 0.96. The labor supply aversion parameter $\varphi$ =1.01. The shares of capital ($\mu$), housing ($\nu$) and labor ($\alpha$) are set as 0.3, 0.03 and 0.64 respectively. The Calvo pricing parameter $\theta$ is 0.75, which is close to the estimate in Christiano *et al* (2005), and the steady state markup $X$ is 1.05. The parameter for housing preference persistence ($\rho_J$) is set at 0.9 reflecting the strong persistence in the data on $J_t$. The responsiveness of housing preference ($\gamma_R$) is 4.5 implying that housing preference is highly sensitive to interest rates. This can be justified in certain circumstances such as in the recent episode of the housing bubble during which market participants raised the leverage ratio to a record high level. The LTV decision rule parameters, $\rho_m$, $\phi_R$ and $\phi_q$ take the values 0.7, -3.2 and 0.3. In the monetary policy rule, as the central bank adjusts interest rates gradually, $\rho_R$ is set at 0.73. The parameters for the responsiveness to inflation ($r_\pi$) and output ($r_Y$) are 0.27 and 0.13, respectively.

[27] Impulse responses of shocks to technology, LTV and housing preferences are provided in Appendix C-3.

**Table 4.1. Calibrated Parameters**

| Parameter | Value | Description |
|---|---|---|
| $\beta_p$ | 0.9925 | Patient households' discount factor |
| $\beta_i$ | 0.9600 | Borrowers' (Impatient households') discount factor |
| $\beta_e$ | 0.9600 | Entrepreneurs' discount factor |
| $\varphi$ | 1.0100 | Labor supply aversion |
| $\mu$ | 0.3000 | Capital share in output |
| $\nu$ | 0.0300 | Housing share in output |
| $\alpha$ | 0.6400 | Labor income share of patient households |
| $\delta$ | 0.0350 | Depreciation rate of capital |
| $\psi_K$ | 2.0000 | Capital adjustment cost |
| $X$ | 1.0500 | Steady-state gross markup |
| $\theta$ | 0.7500 | Probability of maintaining prices |
| $\rho_A$ | 0.6500 | TFP persistence |
| $\rho_J$ | 0.9000 | Housing preference persistence |
| $\gamma_R$ | 4.5000 | Housing preference sensitivity to policy rates |
| $\rho_m$ | 0.7000 | the LTV ratio persistence |
| $\phi_R$ | -3.7000 | the LTV ratio sensitivity to policy rates |
| $\phi_q$ | 0.3000 | the LTV ratio sensitivity to housing prices |
| $\rho_R$ | 0.7300 | Smoothing parameter of the Taylor rule |
| $r_\pi$ | 0.3400 | Inflation coefficient of the Taylor rule |
| $r_Y$ | 0.1300 | Output gap coefficient of the Taylor rule |

### 4.4.2 Monetary Policy Shock

The main aim of the analysis is to study how the transmission mechanism of monetary policy operates in the presence of the *preference channel* and *risk-taking channel.* The benchmark model set up above (termed the *endogenous* model hereafter) endogenized housing preference ($J_t$) and LTV ($m_t$). The contribution from these features in the *endogenous* model is highlighted by comparing it with the *exogenous* model where the housing preference follows a stochastic $AR(1)$ process and the LTV ratio is fixed as in the existing literature.[28] In addition, the impulse responses from the model having a flexible price and no collateral effect are presented to illustrate the effects of imperfections such as a sticky price and collateral

[28] For example, the literature includes Iacoviello (2005), Pariés and Notarpietro (2008), Gerali *et al* (2010) and Iacoviello and Neri (2010).

constraint in both the *endogenous* and *exogenous* model.

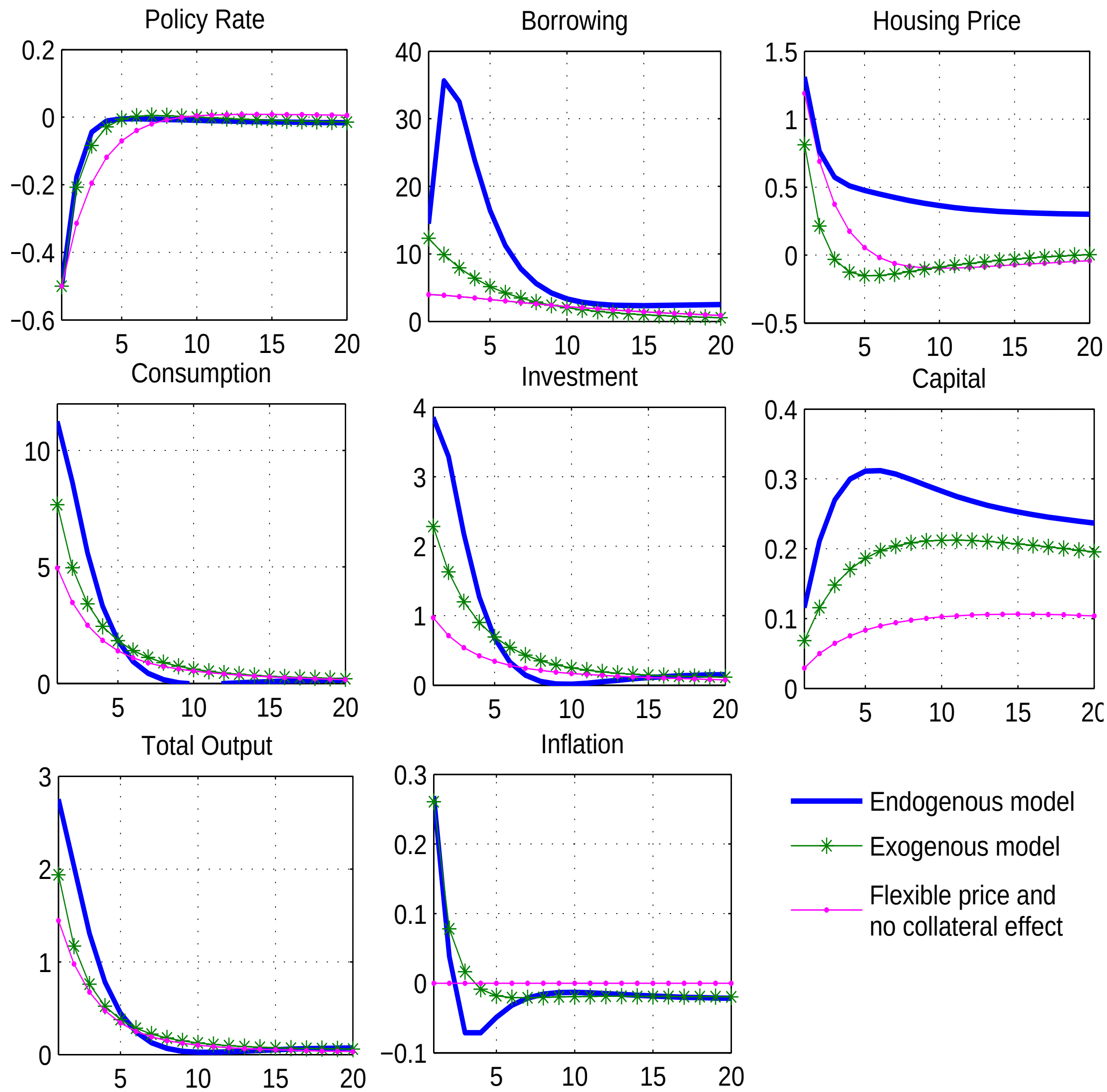
Figure 4.3 plots the responses of the variables in the models to an unanticipated 50 basis points decrease in policy rates. Both the *endogenous* and *exogenous* models reveal the effects generated through the standard collateral channel. As policy rate decreases, households and entrepreneurs borrow more funds from bankers for consuming goods and purchasing houses. The increased demand for housing induces housing price inflation. In turn, appreciation in housing value expands the borrowing capacity of households and entrepreneurs. Analogous to the financial accelerator mechanism, the collateral channel working in these models results in greater impact on housing prices, consumption and investment compared with the model featuring flexible prices and no collateral effect.

Besides the collateral channel, the change in policy rate has an effect through the two additional channels in the *endogenous* model. Lower policy rates shift households' preference toward housing as the user cost of housing diminishes and it also imbues economic agents with an optimistic expectation of future house prices. This impact leads to more borrowing by impatient households and pushes up house prices further than in the *exogenous* model and increases further the value of collateral.

On the other hand, bankers evaluate the default risk of households as lower since they observe housing prices growing robustly and expect a looser monetary policy stance to keep fueling the appetite for housing. Both this observation and optimistic expectations about the future prompt bankers to take more risk by increasing the LTV ratio. As impatient households and entrepreneurs are prepared to borrow to their ceiling amount to maximize their utility, bank lending expands in tandem with increases in the LTV ratio.[29] The confluence of these two additional channels intensifies further the impact of a monetary policy shock on

[29] There are various ways to take on more risk in the mortgage market. For instance, bankers ease lending criteria and invent exotic mortgage products such as the interest-only mortgages.

**Figure 4.3. Impulse Responses to Expansionary Monetary Policy Shock**




Note: The $y$-axis measures percent deviation from the steady state.

bank lending and housing prices *vis*-à-*vis* the case of the *exogenous* model. Increases in the credit to households and entrepreneurs also expands consumption of non-residential goods and investment. Thus, these two channels amplify the effects of monetary policy on the real sector. These reinforcing relationship between bank lending, housing prices, consumption and investment is initiated by the easing of the monetary policy stance in the first phase and is then driven further by credit expansion thereafter. As seen in the Figure 4.3, the substantial deviations of the variables in the model from their steady states are caused fundamentally by the deviation of debt. In this sense, the model economy can be designated as a *credit-driven economy*.

The developments in the *endogenous* model upon the arrival of an expansionary monetary policy shock comply with features observed prior to the sub-prime crisis in the U.S. and in several other developed countries. As interest rates continued to decrease, potential home buyers aggressively took advantage of the opportunity to finance the purchasing of homes by increasing their leverage to a fairly high level. Ampler credit fueled the demand for housing, in turn, pushing up house prices for an extended period. Then, the increase in the value of housing allowed households to refinance mortgages at a lower cost and withdraw a considerable amount of equity by providing their housing as collateral. For mortgage lenders, the appreciation in housing prices acted as a strong incentive to supply more mortgages by increasing the the LTV ratio irrespective of the creditworthiness of borrowers. The upward spiral of housing prices and mortgage lending supported stable growth in consumption expenditure and residential investment in the period of the Great Moderation while elevating housing prices to an unsustainable level.

In summary, endogenizing the impact of monetary policy on the housing preference and bank risk-taking can better explain the apparent co-movements between credit, housing prices, consumption and investment which were observed in the run-up to the sub-prime crisis.

## 4.5 Monetary Policy Reaction to Credit-driven Volatilities

We now assess the benefits of alternative monetary policy rules in stabilizing the overall economy. The loss function of the central bank is defined as the discounted sum of variances of inflation and output gaps following the lead of Levin *et al* (1999).[30]

$$W = E_0 \sum_{t=0}^{\infty} \beta_c^t \left[\lambda \operatorname{var}(\hat{Y}_t) + (1-\lambda) \operatorname{var}(\pi_t)\right] \tag{4.26}$$

where $\hat{Y}_t$ denotes output gap and $\pi_t$ is the rate of inflation. The time preference rate of the central bank $\beta_c^t$ is set as 0.995 and $\lambda$, the indicator of relative preference for minimizing output and inflation volatility, is fixed at 0.5 as in Gilchrist and Saito (2008) and Kannan *et al* (2009).[31]

The standard Taylor rule in equation (4.25) can be re-expressed in *logarithm* as follows.

$$\ln\left(\frac{R_t}{R}\right) = \rho_R \ln R_{t-1} + (1-\rho_R)\left(r_\pi \ln \pi_{t-1} + r_Y \ln\left(\frac{Y_{t-1}}{Y}\right)\right) \tag{4.27}$$

A common alternative interest rate rule in the literature only adds asset prices or housing prices denoted by $q_t$ to the Taylor rule (Bernanke and Gertler, 1999; Iacoviello, 2005). However, in recent research, financial indicators such as credit growth are added to the policy rule to evaluate the contribution of monetary policy reaction to financial and macroeconomic stability.[32] Since the model above features credit constraints and financial intermediation, I also allow for the departure of debt from its steady state (in addition to deviation of housing prices) in specifying alternative rules as follows.

$$\ln\left(\frac{R_t}{R}\right) = \rho_R \ln R_{t-1} + (1-\rho_R)\left(r_\pi \ln \pi_{t-1} + r_Y \ln\left(\frac{Y_{t-1}}{Y}\right) + r_q \ln q_t + r_B \ln b_t\right) \tag{4.28}$$

where $b_t$ is total debt of impatient households ($b_{i,t}$) and entrepreneurs ($b_{e,t}$) in the economy.

[30] The gap is measured by deviation from the steady state. As the steady state of inflation is assumed to be zero in the model, the level equals the gap.

[31] In turns out in the analysis below that the qualitative aspect of the loss function is robust to different values of $\lambda$.

[32] For instance, Kannan *et al* (2009) augments the Taylor rule by adding the growth rate of nominal credit while Gray *et al* (2011) added possible default of the banking system to the rule.

The performances of each of the following six rules are compared: (i) Taylor rule with inflation only ($IR$); (ii) standard Taylor rule ($TR$); (iii) Taylor rule augmented by housing prices ($TRH$); (iv) Taylor rule augmented by debt ($TRB$); (v) $TRB$ responding aggressively to debt volatility ($ATRB$); (vi) Taylor rule augmented by debt and housing prices ($TRBH$). The specific values of the parameters for each rule are set out in Table 4.2.

**Table 4.2. Monetary Policy Rules**

| Rule | $\rho_R$ | $r_\pi$ | $r_Y$ | $r_q$ | $r_b$ |
|---|---|---|---|---|---|
| $IR$ | 0.7 | 1.5 | - | - | - |
| $IB$ | 0.7 | 1.5 | - | 0.3 | - |
| $TR$ | 0.7 | 1.5 | 0.2 | - | - |
| $TRH$ | 0.7 | 1.5 | 0.2 | 0.3 | - |
| $TRB$ | 0.7 | 1.5 | 0.2 | - | 0.3 |
| $ATRB$ | 0.7 | 1.5 | 0.2 | - | 1.0 |
| $TRBH$ | 0.7 | 1.5 | 0.2 | 0.3 | 0.3 |

Note: $IR \equiv$ Policy rule responding only to inflation, $IB \equiv$ Policy rule responding to inflation and debt, $TRH \equiv$ Taylor rule augmented by housing price, $TRB \equiv$ Taylor rule augmented by debt, $ATRB \equiv$ Aggressive $TRB$, $TRBH \equiv$ Taylor rule augmented by debt and housing price.

Table 4.3 displays the relative performance of the policy rules. The following points are noteworthy: first, the augmented Taylor rule allowing for debt volatility ($TRB$) reduces the loss more than the standard Taylor rule ($TR$). Second, the gains attained by the augmented rule including housing price fluctuations ($TRH$) are marginal compared with $TR$. Third, responding aggressively to the debt volatility ($ATRB$) minimizes the loss function. Finally and most importantly, the rule responding to inflation and debt volatility rather than output gap ($IB$) performs better than the standard Taylor rule $TR$.[33] The final two observations provide an implication for monetary policy during a period characterized by excessive risk-taking and an overheated demand for housing. The central bank has to consider responding to credit volatility if it judges that the economy is being propelled by the rapid growth of credit rather than solid economic fundamentals. Attention should, in particular, be drawn to the fact that a more aggressive stance towards credit growth performs better for the purpose

[33] The loss from the standard Taylor rule with aggressive response to output gap ($r_Y = 1.0$) is 0.0285 which is higher than the augmented Taylor rule aggressively responding to debt, $ATRB$.

of macroeconomic stability.

**Table 4.3. Performance of Policy Rules to Monetary Policy Shock**

| Rule | Performance Rank | Loss | $SD$ of $\hat{Y}$ | $SD$ of $\pi$ |
|---|---|---|---|---|
| $IR$ | 7 | 0.4891 | 0.9840 | 0.1000 |
| $IB$ | 2 | 0.1263 | 0.4715 | 0.1739 |
| $TR$ | 6 | 0.1801 | 0.5988 | 0.0413 |
| $TRH$ | 5 | 0.1726 | 0.5716 | 0.1257 |
| $TRB$ | 4 | 0.1538 | 0.5164 | 0.2024 |
| $ATRB$ | 1 | 0.0044 | 0.0833 | 0.0099 |
| $TRBH$ | 3 | 0.1463 | 0.5051 | 0.1937 |

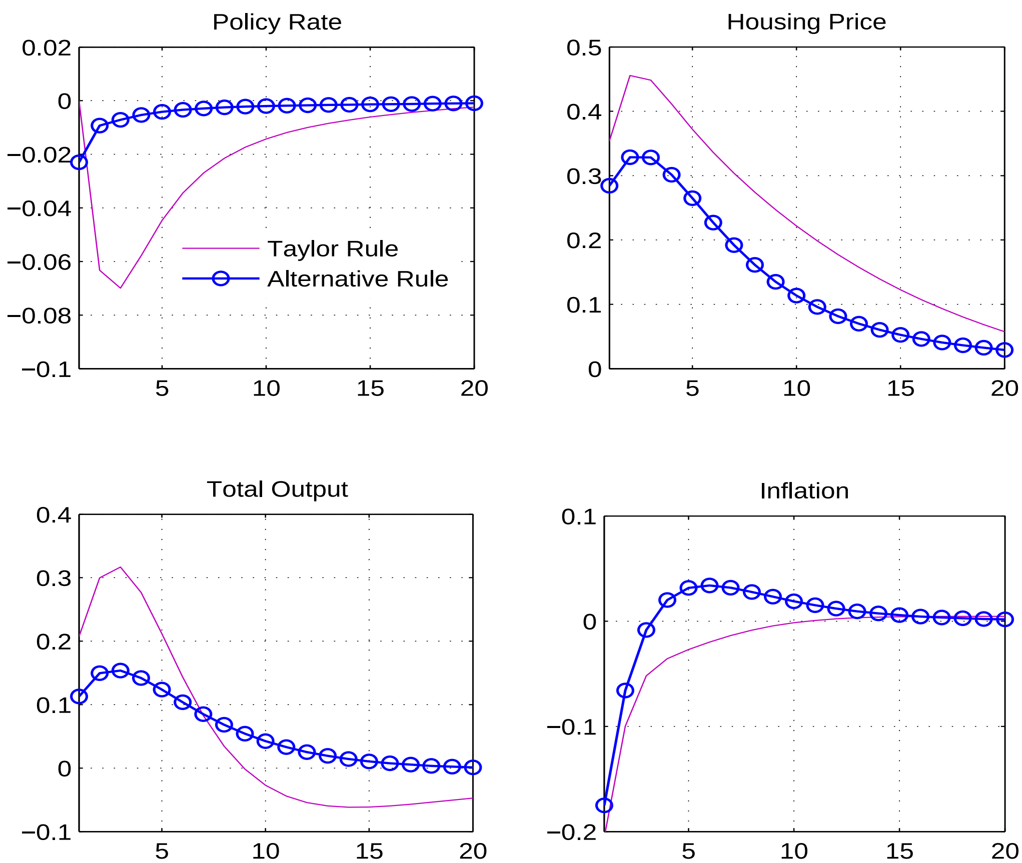
Notes: 1. $IR \equiv$ Policy rule responding only to inflation, $IB \equiv$ Policy rule responding to inflation and debt, $TRH \equiv$ Taylor rule augmented by housing price, $TRB \equiv$ Taylor rule augmented by debt, $ATRB \equiv$ Aggressive $TRB$, $TRBH \equiv$ Taylor rule augmented by debt and housing price.
2. $SD$ denotes standard deviation.

In our analysis, the augmented Taylor rule, which reacts positively to excessive debt growth, performs best in stabilizing the economy subject to a monetary policy shock.

Figure 4.4 displays the impulse responses of policy rates, housing prices, output and inflation in response to a TFP shock under two rules: (i) the standard Taylor rule ($TR$ above) and (ii) the augmented Taylor rule responding aggressively to debt with $r_b = 1$ ($ATRB$). The alternative rule dampens appreciably the deviations of housing prices and output from the steady states while the gain with inflation is relatively marginal. An additional benefit is the smoother path of policy rates which can lessen the negative repercussions on the whole economy resulting from rapid adjustments of the policy stance.

Overall, the results from this analysis provide credence to the arguments from recent research that adding financial indicators to a policy rule can enhance macroeconomic stability when the economy is vulnerable to financial instability (see for instance, Curdia and Woodford, 2009; Kannan *et al*, 2009; Gertler and Karadi, 2011; Gray *et al*, 2011).

**Figure 4.4. Impulse Responses to TFP Shock under Different Policy Rules**




Note: The $y$-axis measures percent deviation from the steady state.

## 4.6 Conclusion

Two main reflections following the sub-prime crisis have received growing attention among central bankers and academic economists. First, the failure in identifying transmission channels through the financial sector and housing market led to an underestimation of the full influence of monetary policy decisions on the overall economy. Subsequently, these failures led to the inadequate reaction of policy makers to the rapidly increasing leverage and demand for housing. The second reflection from the academic perspective is that prevalent macroeconomic models, whether they be Neoclassical or New Keyensian, ignored the role of the financial sector, in particular, the implications of financial intermediation, for business cycle fluctuations.

The first aim of this chapter was to accommodate these reflections into an existing workhorse model featuring the housing market and credit constraint by endogenizing additional transmission channels of monetary policy. Secondly, we tried to find an optimal monetary policy reaction function that could moderate the volatilities of a monetary policy shock.

The model included two additional transmission routes of monetary policy decisions: (i) direct impacts on the housing demand through the *preference channel*; and (ii) the *risk-taking channel* operating in the banking sector. An expansionary monetary policy shock increases the preference for housing as the borrowing costs decrease and people hold optimistic expectations of future capital gains. Furthermore, as the increased demand pushes up the price of housing offered as collateral, bankers perceive a lower default risk of collateralized lending. The combination of low risk-perception and higher risk-tolerance leads to aggressive mortgage lending on the part of banks by increasing the LTV ratio.

The integration of these channels into the workhorse framework of Iacoviello (2005) entails more prominent fluctuations of credit, housing prices and real variables when there is an unexpected decrease in policy rates. The main reason for this lies in the different paths of the total debt between the *endogenous* and *exogenous* models. In the *endogenous* model, borrowing capacity is expanded by a rise in the LTV ratio and the demand for housing increases as preference shifts toward it with a monetary policy shock. This increases debt, which in turn drives up house purchases, consumption and entrepreneurial investment. As such the model economy is propelled mainly by rapid credit growth and, for that reason, it is designated as the *credit-driven economy.*

A normative question can be asked whether it suffices for the central bank to respond with the conventional Taylor rule to *credit-driven* volatilities in achieving stable paths of inflation and output. Comparing the performance of alternative policy rules reveals that positive reactions to debt volatility can improve significantly macroeconomic stability relative to the standard Taylor rule. On the other hand, the benefit from responding to housing prices turns out to be negligible.

These results deliver several useful implications for implementing monetary policy to attain the goal of macroeconomic stability. First, if the unambiguous symptoms of the *credit-driven* economy are detected, such as rapid growth in collateralized debt and housing prices alike, the central bank needs to consider the debt-responding rule as a short-term strategy to stabilize the economy. For implementing the strategy efficiently, a close monitoring of the mortgage market and timely procurement by the central bank of the relevant information are prerequisites. Second, the economy can become more stable by reacting to credit volatility instead of housing price fluctuations. Lastly and most importantly, as we learned from the recent crisis, the transmission mechanism of monetary policy has been undergoing drastic changes due to several factors. These factors include innovative developments of the financial sector, increases in the amount of information accessible to the public, and increased rationality in expectation formation. To overcome this formidable challenge that monetary policy transmission mechanism is possibly evolving rapidly without being noticed, central banks need to pay close attention to hitherto undiscovered transmission channels to make monetary policy implementation more effective in fulfilling its mandate of sound economic growth and price stability.

# Conclusion

There have been remarkable achievements in the research on the role played by monetary policy decisions in generating the housing cycle and on an optimal reaction of monetary policy to exuberance in the housing market. Regarding the first issue, several empirical findings after the sub-prime crisis demonstrate that monetary policy decisions to maintain low policy rates for the extended period have stimulated the demand for housing through multiple transmission channels and are largely accountable for the recent housing boom and bust episode. Moreover, researchers find that an aggressive policy reaction to abnormal behaviour of credit and asset prices is recommended for maximizing social benefit relative to the traditional approach.

The main points presented in this thesis are broadly in line with the above findings. Firstly, interest rates, particularly short-term policy rates, have played a prime role in generating the past housing cycles thorough several transmission channels. Secondly, monetary policy easing can amplify the volatility of the overall economy through the housing market by reinforcing not only the risk-taking tendency of mortgage suppliers but also the preference of economic agents toward housing. Lastly, the central bank can enhance macroeconomic stability if it responds to an excessive growth of credit and asset prices by raising its policy rates. Further implications derive from these main findings. As a result of rapid liberalization in the financial sector and increased accessibility of the public to information, the transmission mechanism of monetary policy may have underwent drastic changes. The challenge demands that central bankers should pay a special heed to the possibility that novel transmission channels, such as the *risk-taking channel* and *preference channel* discussed in this thesis, may magnify or distort the originally intended impact. Turning to the regulatory issue, imposition of a lower ceiling on LTV ratio or limitation on the growth rate of bank credit can be a useful measure in conjunction with monetary policy reactions to inhibit overshooting of house prices and prevent its negative spillover effects to the real sector.

The focus of this thesis is on searching for a relevant monetary policy reaction in the boom phase of the housing cycle. However it is also crucial to find how the central bank should implement monetary policy in the downturn of the housing market. Even though the Federal Reserve reacted to the housing market crash and its subsequent systemic breakdown of the banking sector by lowering policy rates effectively to zero and continuous rounds of the quantitative easing, central banks of the countries experiencing a negative aftermath emanating solely from the housing market slowdown (such as Korea) may require a different policy path. Specifically, it is debatable whether central banks should attempt to deflate the remaining bubble in the housing market by tightening monetary policy for hastening economic recovery or to bolster the current level of house prices by easing their policy stance in order to reduce the volatility of economic activities. This issue, exactly like the question about whether the central bank should step in amidst a housing market boom, is accompanied by several intricacies. First, it continues to be necessary to judge whether the current level of house prices is overly inconsistent with economic fundamentals. Second, the derivative effects of policy rate changes on other economic sectors should be evaluated as accurately as possible. A cost-benefit analysis of two alternative policy stances is required.

An additional research topic for the future is understanding how expectations in the housing market are formed and measuring the transmission effects of monetary policy conditional on them. Over the past decade, it has become widely recognized that expectations are among the key drivers of the housing cycle and exert powerful influences in the boom phase of the housing market. Several characteristics of home-buyers' expectations have been recognized. For example, as confirmed by several empirical studies introduced in Chapter 2, expectations are formed in a backward-looking fashion. One of the most important recent findings presented by Case *et al* (2012) suggests that long-term expectations of future house prices was a more potent driver of the bubble phenomenon in the U.S. than short-term ones. However, Shiller (2012) mentions that it is still not fully understood why the public had extravagant expectations in the midst of the housing boom and why they changed so swiftly to a sober state. These questions will be among the important ones to ask in research on housing in the foreseeable future.

**A. Data Source for Regression of House Prices Deviation in U.S.**

| | Data | Change Rate | Data Source |
|---|---|---|---|
| Nominal House Price Index | S&P/Case-Shiller House Price Index | | Standard & Poor's |
| | National House Price Index | | FHFA |
| Deflator for Real House Price | Consumer Price Index less shelter | | BLS |
| Short-term Interest Rate | Federal Funds Rate | Change in the level against previous quarter (%p) | Fed |
| Long-term Interest Rate | National Average Mortgage Interest Rate (Average maturity of 27.5 years from 1987 to 2009) | Change in the level against previous quarter (%p) | FHFA |
| Income | Disposable Personal Income per capita | 4-quarter change (%) | BEA |
| Real Estate Loan | Commercial Banks' Real Estate Loan for Home and Commercial Estate | 4-quarter change (%) | Fed |
| General Price Level | Consumer Price Index (Base Period : 1982-84=100) | 4-quarter change (%) | BLS |
| Demographic Change | Number of civilians aged 15 to 54 | 4-quarter change (%) | BLS |

Note: BEA (Bureau of Economic Analysis), BLS (Bureau of Labor Statistics), Federal Reserve, FHFA (Federal Housing Finance Agency)

## B-1. Proof of the Borrowing Constraint Binding at Steady State

The Euler equation derived from the patient households' optimization is given by

$$\frac{1}{c_t^P} = \beta_P E_t\Big(\frac{R_t}{c_{t+1}^P \pi_{t+1}}\Big)$$

and the corresponding steady state is

$$\frac{1}{c^P} = \beta_P \frac{R}{c^P \pi}$$

and as inflation is assumed to be zero at the steady state, namely, $\pi = 1$,

$$R = \frac{1}{\beta_P} \tag{S1}$$

Turning to the Euler equation for the impatient households,

$$\frac{1}{c_t^B} = \beta_B E_t\Big(\frac{R_t}{c_{t+1}^B \pi_{t+1}}\Big) + \lambda_t R_t$$

and the corresponding steady state is

$$\frac{1}{c^B} = \beta_B \frac{R}{c^B \pi} + \lambda R \tag{S2}$$

Substituting (S1) into (S2) and arranging the terms about $\lambda$ yields

$$\lambda = \frac{\beta_P - \beta_B}{c} \tag{S3}$$

Since $\beta_P - \beta_B > 0$ by the assumption, $\lambda$ is over zero at the steady state. As the original $\lambda_t$ measures the increment in the lifetime utility of impatient households accrued by increases in borrowing, there is always a scope for increasing utility as long as $\lambda$ is positive. Hence impatient households borrow the upper limit of the borrowing constraint.

## B-2: Necessary Equilibrium Conditions

### 1. Patient Households as Lenders

$$\frac{1}{c_t^P} = \beta_P E_t\Big(\frac{R_t}{c_{t+1}^P \pi_{t+1}}\Big) \tag{N1}$$

$$w_t^P = c_t^P (L_t^P)^{\eta-1} \tag{N2}$$

$$\frac{q_t}{c_t^P} = \frac{j}{h_t^P} + \beta_P E_t\Big(\frac{q_{t+1}}{c_{t+1}^P}\Big) \tag{N3}$$

$$m_t = m_{t-1}^{\rho_m} (R_{t-1}^{\rho_R} q_{t-1}^{\rho_q})^{1-\rho_m} e_t^m \tag{N4}$$

### 2. Impatient Households

$$\frac{1}{c_t^B} = \beta_B E_t\Big(\frac{R_t}{c_{t+1}^B \pi_{t+1}}\Big) + \lambda_t R_t \tag{N5}$$

$$w_t^B = c_t^B (L_t^B)^{\eta-1} \tag{N6}$$

$$\frac{q_t}{c_t^B} = \frac{j}{h_t^B} + E_t\Big(\beta_B \frac{q_{t+1}}{c_{t+1}^B} + m_t \lambda_t q_{t+1} \pi_{t+1}\Big) \tag{N7}$$

$$c_t^B + q_t(h_t^B - h_{t-1}^B) + \frac{R_{t-1} b_{t-1}^B}{\pi_t} = b_t^B + w_t^B L_t^B + T_t - \Delta(\frac{M_t^B}{P_t}) \tag{N8}$$

$$b_t = m_t E_t(\frac{q_{t+1} h_t^B \pi_{t+1}}{R_t}) \tag{N9}$$

### 3. Firms

$$w_t^P = \alpha \frac{Y_t}{X_t L_t^P} \tag{N10}$$

$$w_t^B = (1-\alpha) \frac{Y_t}{X_t L_t^B} \tag{N11}$$

$$\frac{Y_t}{X_t} = w_t^P L_t^P + w_t^B L_t^B \tag{N12}$$

## 4. Retailers

$$P_t^* = X \sum_{k=0}^{\infty} \left[ \frac{(\theta\beta)^k E_t \left( \Lambda_{tk} Y_{t+k}^{*f} P_{t+k}^{-1} \right)}{\sum_{k=0}^{\infty} (\theta\beta)^k E_t \left( \Lambda_{tk} Y_{t+k}^{*f} P_{t+k}^{-1} \right)} \right] E_t \left( \frac{1}{X_{t+k}^n} \right)$$

$$P_t = \left[ \theta P_{t-1}^{\varepsilon} + (1-\theta)(P_t^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{N13}$$

## 5. Central Bank

$$R_t = [R_{t-1}]^{r_R} \left[ \pi_{t-1}^{1+r_\pi} \left( \frac{Y_{t-1}}{Y} \right)^{r_Y} \overline{rr} \right]^{1-r_R} e_t^R \tag{N14}$$

## 6. Market Clearance

$$c_t^P + c_t^B = Y_t \tag{N17}$$

$$h_t^P + h_t^B = \bar{H} \tag{N18}$$

$$s_t^P = b_t^B \tag{N19}$$

## B-3. Log-linearized Conditions

### 1. Patient Households as Lenders

$$\hat{c}_t^P = E_t \hat{c}_{t+1}^P - \hat{rr}_t \tag{L1}$$

$$\hat{q}_t = \beta_P E_t(\hat{q}_{t+1}) + \iota \hat{h}_t^B + \hat{c}_t^P - \beta_P E_t(\hat{c}_{t+1}^P) \quad \text{where} \quad \iota = (1-\beta_P)\frac{h^B}{h^P} \tag{L2}$$

$$\hat{m}_t = \rho_m \hat{m}_{t-1} + (1-\rho_m)(\rho_R \hat{R}_{t-1} + \rho_q \hat{q}_{t-1}) + \hat{e}_t^m \tag{L3}$$

### 2. Impatient Households

$$\begin{aligned}\hat{q}_t = (1-m\beta_P)\hat{c}_t^B - \beta_B(1-m)E_t\hat{c}_{t+1}^B + [\beta_B + m(\beta_P - \beta_B)]E_t\hat{q}_{t+1} \\ + m(\beta_P - \beta_B)\hat{m}_t - m\beta_P \widehat{rr}_t - \frac{q}{c^B}\frac{j}{h^B}\hat{h}_t^B\end{aligned} \tag{L4}$$

$$c^B \hat{c}_t^B = -qh^B \Delta \hat{h}_t^B - Rb^B(\hat{R}_{t-1} + \hat{b}_{t-1}^B - \pi_t) + b^B \hat{b}_t^B + (1-\alpha)\frac{Y}{X}(\hat{Y}_t - \hat{X}_t) \tag{L5}$$

$$\hat{b}_t^B = \hat{m}_t + E_t q_{t+1} + \hat{h}_t^B - \widehat{rr}_t \tag{L6}$$

### 3. Aggregate Supply

$$\hat{Y}_t = \hat{X}_t + \eta \hat{L}_t^P + \hat{c}_t^P \tag{L7}$$

$$\hat{Y}_t = \hat{X}_t + \eta \hat{L}_t^B + \hat{c}_t^B \tag{L8}$$

$$\hat{Y}_t = \alpha \hat{L}_t^P + (1-\alpha)\hat{L}_t^B \tag{L9}$$

## 4. Inflation Dynamics: New Keyensian Phillips Curve

$$\hat{\pi}_t = \beta_P E_t \hat{\pi}^{t+1} - \kappa \hat{X}_t$$

$$\text{where } \kappa = \frac{(1-\theta)(1-\beta_P\theta)}{\theta} \tag{L10}$$

## 5. Central Bank

$$\hat{R}_t = r_R \hat{R}_{t-1} + (1-r_R)\big[(1+r_\pi)\hat{\pi}_{t-1} + r_Y \hat{Y}_{t-1}\big] + r_R \hat{R}_{t-1} + \hat{e}_t^R \tag{L11}$$

## 6. Equilibrium in Goods, Housing and Lending Markets

$$\hat{Y}_t = \frac{c^P}{c^P + c^B}\hat{c}_t^P + \frac{c^B}{c^P + c^B}\hat{c}_t^B \tag{L12}$$

$$0 = h^P \hat{h}_t^P + h^B \hat{h}_t^B \tag{L13}$$

$$\hat{s}_t^P = \hat{b}_t^B \tag{L14}$$

## C-1. Necessary Equilibrium Conditions

### 1. Patient Households

$$\frac{1}{c_{p,t}} = \beta_p E_t\left(\frac{R_t}{\pi_{t+1} c_{p,t+1}}\right) \tag{N1}$$

$$\begin{aligned}&\frac{q_t}{c_{p,t}}\left[1+\psi_h\left(\frac{\Delta h_{p,t}}{h_{p,t-1}}\right)\right]\\ &\quad = \frac{J_t}{h_{p,t}} + E_t\left\{\beta_p \frac{q_{t+1}}{c_{p,t+1}}\left[1+\psi_h\left(\frac{\Delta h_{p,t+1}}{h_{p,t}}\right)\frac{h_{p,t+1}}{h_{p,t}} - \frac{\psi_h}{2}\left(\frac{\Delta h_{p,t+1}}{h_{p,t}}\right)^2\right]\right\}\end{aligned} \tag{N2}$$

$$w_{p,t} = (L_{p,t})^{\varphi-1} c_{p,t} \tag{N3}$$

$$\begin{aligned}&c_{p,t} + q_t(h_{p,t} - h_{p,t-1}) + S_t\\ &\quad = \frac{R_{t-1}S_{t-1}}{\pi_t} + w_{p,t}L_{p,t} + N_t + T_{p,t} - \frac{\Delta M_{p,t}}{P_t} - \frac{\psi_h}{2}\left(\frac{\Delta h_{p,t}}{h_{p,t-1}}\right)^2 q_t h_{p,t-1}\end{aligned} \tag{N4}$$

## 2. Impatient Households

$$\frac{1}{c_{i,t}} = \beta_i E_t\left(\frac{R_{i,t}}{\pi_{t+1}c_{i,t+1}}\right) + \lambda_{i,t}R_t \tag{N5}$$

$$\frac{q_t}{c_{i,t}}\left[1+\psi_h\left(\frac{\Delta h_{i,t}}{h_{i,t-1}}\right)\right]$$
$$= \frac{J_t}{h_{i,t}} + \beta_i E_t\left[\frac{q_{t+1}}{c_{i,t+1}}\left(1+\psi_h\left(\frac{\Delta h_{i,t+1}}{h_{i,t}}\right)\frac{h_{i,t+1}}{h_{i,t}} - \frac{\psi_h}{2}\left(\frac{\Delta h_{i,t+1}}{h_{i,t}}\right)^2\right) + \lambda_{i,t}m_{i,t}q_{t+1}\pi_{t+1}\right] \tag{N6}$$

$$w_{i,t} = (L_{i,t})^{\varphi-1}c_{i,t} \tag{N7}$$

$$\frac{\chi}{m_{i,t}} = \frac{1}{c_{i,t}} - \beta_i E_t\left(\frac{1}{c_{i,t+1}}\pi_{t+1}\right) \tag{N8}$$

$$c_{i,t} + q_t(\Delta h_{i,t}) + \frac{R_{i,t-1}b_{i,t-1}}{\pi_t}$$
$$= b_{i,t} + w_{i,t}L_{i,t} + T_{i,t} - \frac{\Delta M_{i,t}}{P_t} - \frac{\psi_h}{2}\left(\frac{\Delta h_{i,t}}{h_{i,t-1}}\right)^2 q_t h_{i,t-1} \tag{N9}$$

$$b_{i,t} = m_{i,t}E_t\left(\frac{q_{t+1}h_{i,t}\pi_{t+1}}{R_t}\right) \tag{N10}$$

## 3. Entrepreneurs

$$\frac{1}{c_{e,t}} = \beta_e E_t \left( \frac{R_{e,t}}{\pi_{t+1} c_{e,t+1}} \right) + \lambda_t R_t \tag{N11}$$

$$\frac{q_t}{c_{e,t}} = \frac{1}{c_{e,t}} \left[ \psi_h \left( \frac{\Delta h_{e,t}}{h_{e,t-1}} \right) q_t \right] + \lambda_t m_{e,t} E_t(q_{t+1}\pi_{t+1})$$
$$+ \beta_e E_t \left\{ \frac{1}{c_{e,t+1}} \left[ \nu \frac{Y_{t+1}}{h_{e,t} X_{t+1}} + q_{t+1} + \psi_h \left( \frac{\Delta h_{e,t+1}}{h_{e,t}} \right) q_{t+1} \left( \frac{h_{e,t+1}}{h_{e,t}} - \frac{1}{2} \left( \frac{\Delta h_{e,t+1}}{h_{e,t}} \right) \right) \right] \right\} \tag{N12}$$

$$w_{p,t} = \alpha(1-\mu-\nu) \frac{Y_t}{X_t L_{p,t}} \tag{N13}$$

$$w_{i,t} = (1-\alpha)(1-\mu-\nu) \frac{Y_t}{X_t L_{i,t}} \tag{N14}$$

$$\frac{1}{c_{e,t}} \left[ 1 + \frac{\psi_K}{\delta} \left( \frac{I_t}{K_{t-1}} - \delta \right) \right]$$
$$= E_t \left\{ \frac{\beta_e}{c_{e,t+1}} \left[ \mu \frac{Y_{t+1}}{X_{t+1} K_t} + (1-\delta) + \frac{\psi_K}{\delta} \left( \frac{I_{t+1}}{K_t} - \delta \right) \left( \frac{1}{2} \left( \frac{I_{t+1}}{K_t} + \delta \right) + 1 - \delta \right) \right] \right\} \tag{N15}$$

$$\frac{Y_t}{X_t} + b_{e,t} = c_{e,t} + q_t(\Delta h_{e,t}) + \frac{R_{e,t-1} b_{e,t-1}}{\pi_t} + w_{p,t} L_{p,t} + w_{i,t} L_{i,t} + I_t$$
$$+ \frac{\psi_K}{2\delta} \left( \frac{I_t}{K_{t-1}} - \delta \right)^2 K_{t-1} + \frac{\psi_h}{2} \left( \frac{\Delta h_{e,t}}{h_{e,t-1}} \right)^2 q_t h_{e,t-1} \tag{N16}$$

$$b_{e,t} = m_{e,t} E_t \left( \frac{q_{t+1} h_{e,t} \pi_{t+1}}{R_t} \right) \tag{N17}$$

$$Y_t = A_t K_{t-1}^{\mu} h_{e,t-1}^{\nu} (L_{p,t})^{\alpha(1-\mu-\nu)} (L_{i,t})^{(1-\alpha)(1-\mu-\nu)} \tag{N18}$$

$$I_t = K_t - (1-\delta) K_{t-1} \tag{N19}$$

## 3. Housing Preference

$$J_t = (1-\rho_J)\, \bar{J}\, \frac{J_{t-1}^{\rho_J}}{R_{t-1}^{\gamma_R}}\, u_{J,t} \tag{N20}$$

## 5. Retailers

$$\sum_{k=0}^{\infty}(\theta\beta_p)^k E_t \left\{ \Lambda_{tk} \left[ \frac{P_t^*(z)}{P_{t+k}} - \frac{X}{X_{t+k}} \right] Y_{t+k}^*(z) \right\} = 0 \tag{N21}$$

$$P_t^{1-\epsilon} = \theta P_{t-1}^{1-\epsilon} + (1-\theta)(P_{t-1}^*)^{1-\epsilon} \tag{N22}$$

$$F_t = \frac{(X_t - 1)}{X_t} Y_t \tag{N23}$$

## 6. Central Bank

$$R_t = R_{t-1}^{\rho_R} \left( \pi_{t-1}^{r_\pi} \left( \frac{Y_{t-1}}{Y} \right)^{r_Y} \overline{rr} \right)^{1-\rho_R} u_{R,t} \tag{N24}$$

## 7. Banking Sector

$$m_t = \frac{m_{t-1}^{\rho_m} \, q_{t-1}^{\phi_q}}{R_{t-1}^{\phi_R}} \, u_{m,t} \tag{N25}$$

## 8. Market Clearance

$$H = h_{p,t} + h_{i,t} + h_{e,t} \tag{N26}$$

$$Y_t = c_{p,t} + c_{i,t} + c_{e,t} + I_t \tag{N27}$$

$$D_t = L_{i,t} + L_{e,t} \tag{N28}$$

## C-2. Log-linearized model

### 1. Aggregate Demand

$$\beta_p \hat{c}_{e,t} = \beta_p E_t \hat{c}_{e,t+1} + \beta_e E_t \hat{\pi}_{t+1} - \beta_p \hat{R}_t - (\beta_p - \beta_e)\hat{\lambda}_t \tag{L1}$$

$$\hat{c}_{e,t} = \hat{c}_{e,t+1} - \zeta \left(\hat{Y}_{t+1} - \hat{X}_{t+1} - \hat{K}_t\right) + \psi_K \left[\hat{I}_t - \hat{K}_{t-1} - \beta_e \left(\hat{I}_{t+1} - \hat{K}_t\right)\right] \tag{L2}$$

$$\hat{c}_{p,t} = E_t \hat{c}_{p,t+1} - \hat{R}_t + E_t \hat{\pi}_{t+1} \tag{L3}$$

$$\beta_p \hat{c}_{i,t} = \beta_p E_t \hat{c}_{i,t+1} - (\beta_p - \beta_i)\hat{\lambda}_{i,t} - \beta_p \hat{R}_t + \beta_i E_t \hat{\pi}_{t+1} \tag{L4}$$

$$\frac{c_e}{Y}\hat{c}_{e,t} + \frac{c_p}{Y}\hat{c}_{p,t} + \frac{c_i}{Y}\hat{c}_{i,t} + \frac{I}{Y}\hat{I}_t - \hat{Y}_t = 0 \tag{L5}$$

where $\zeta = 1 - \beta_e(1-\delta)$

### 2. Housing Market

$$\begin{aligned}\hat{q}_t = {} & \gamma_e E_t \hat{q}_{t+1} + (1-\gamma_e)\, E_t \left(\hat{Y}_{t+1} - \hat{h}_{e,t} - \hat{X}_{t+1}\right) \\ & + \psi_e \hat{m}_{e,t}\, E_t \left(\hat{\lambda}_t + \hat{\pi}_{t+1} + \hat{c}_{e,t+1}\right) + \hat{c}_{e,t} - E_t \hat{c}_{e,t+1}\end{aligned} \tag{L6}$$

$$\hat{q}_t = \beta_p E_t \hat{q}_{t+1} + (1-\beta_p)\left(\hat{J}_t - \hat{h}_{p,t}\right) + \hat{c}_{e,t} - \beta_p E_t \hat{c}_{e,t+1} \tag{L7}$$

$$\hat{q}_t = \gamma_h E_t \hat{q}_{t+1} + (1-\gamma_h)\left(\hat{J}_t - \hat{h}_{i,t}\right) + \psi_h \hat{m}_{i,t}\, E_t \left(\hat{\lambda}_{i,t} + \hat{\pi}_{t+1}\right) + \hat{c}_{i,t} - \beta_i E_t \hat{c}_{i,t+1} \tag{L8}$$

$$0 = h_e \hat{h}_{e,t} + h_p \hat{h}_{p,t} + h_i \hat{h}_{i,t} \tag{L9}$$

where $\gamma_e = \beta_e + m_e(\beta_p - \beta_e)$, $\psi_e = m_e(\beta_p - \beta_e)$, $\gamma_h = \beta_i + m_i(\beta_p - \beta_i)$ and $\psi_h = m_i(\beta_p - \beta_i)$.

### 3. Housing Preference

$$\hat{J}_t = \rho_J\, \hat{J}_{t-1} + \gamma_R\, R_{t-1} + \hat{u}_{J,t} \tag{L10}$$

## 4. Borrowing Constraint

$$\hat{b}_{i,t} = \hat{m}_{i,t} + E_t\hat{q}_{t+1} + \hat{h}_{i,t} + E_t\hat{\pi}_{t+1} - \hat{R}_t \tag{L12}$$

$$\hat{b}_{e,t} = \hat{m}_{e,t} + E_t\hat{q}_{t+1} + \hat{h}_{e,t} + E_t\hat{\pi}_{t+1} - \hat{R}_t \tag{L11}$$

## 5. Aggregate Supply

$$\hat{Y}_t = \hat{X}_t + \varphi\hat{L}_{p,t} + \hat{c}_{p,t} \tag{L13}$$

$$\hat{Y}_t = \hat{X}_t + \varphi\hat{L}_{e,t} + \hat{c}_{i,t} \tag{L14}$$

$$\begin{aligned}\hat{Y}_t = {} & \hat{A}_t + \mu\hat{K}_{t-1} + \nu\hat{h}_{e,t-1} \\ & + \alpha(1-\mu-\nu)\hat{L}_{p,t} + (1-\alpha)(1-\mu-\nu)\hat{L}_{i,t}\end{aligned} \tag{L15}$$

$$\hat{\pi}_t = \beta_p E_t\hat{\pi}_{t+1} - \kappa\hat{X}_t \tag{L16}$$

## 6. Flows of Funds

$$\begin{aligned}\frac{b_e}{Y}\hat{b}_{e,t} = {} & \frac{c_e}{Y}\hat{c}_{e,t} + \frac{h_e q}{Y}(\hat{h}_{e,t} - \hat{h}_{e,t-1}) + \frac{I}{Y}\hat{I}_t + \frac{Rb_e}{Y}(\hat{R}_{t-1} + \hat{b}_{e,t-1} - \hat{\pi}_t) \\ & - (1 - s' - s'')(\hat{Y}_t - \hat{X}_t)\end{aligned} \tag{L17}$$

$$\hat{K}_t = \delta\hat{I}_t + (1-\delta)\hat{K}_{t-1} \tag{L18}$$

$$\frac{b_i}{Y}\hat{b}_{i,t} = \frac{c_i}{Y}\hat{c}_{i,t} + \frac{qh_i}{Y}(\hat{h}_{i,t} - \hat{h}_{i,t-1}) + \frac{Rb_i}{Y}(\hat{R}_{t-1} + \hat{b}_{i,t-1} - \hat{\pi}_t) - s'(\hat{Y}_t - \hat{X}_t) \tag{L19}$$

where $s' = \dfrac{\alpha(1-\mu-\nu) + X - 1}{X}$ and $s'' = \dfrac{(1-\alpha)(1-\mu-\nu)}{X}$.

## 7. Monetary Policy Rule

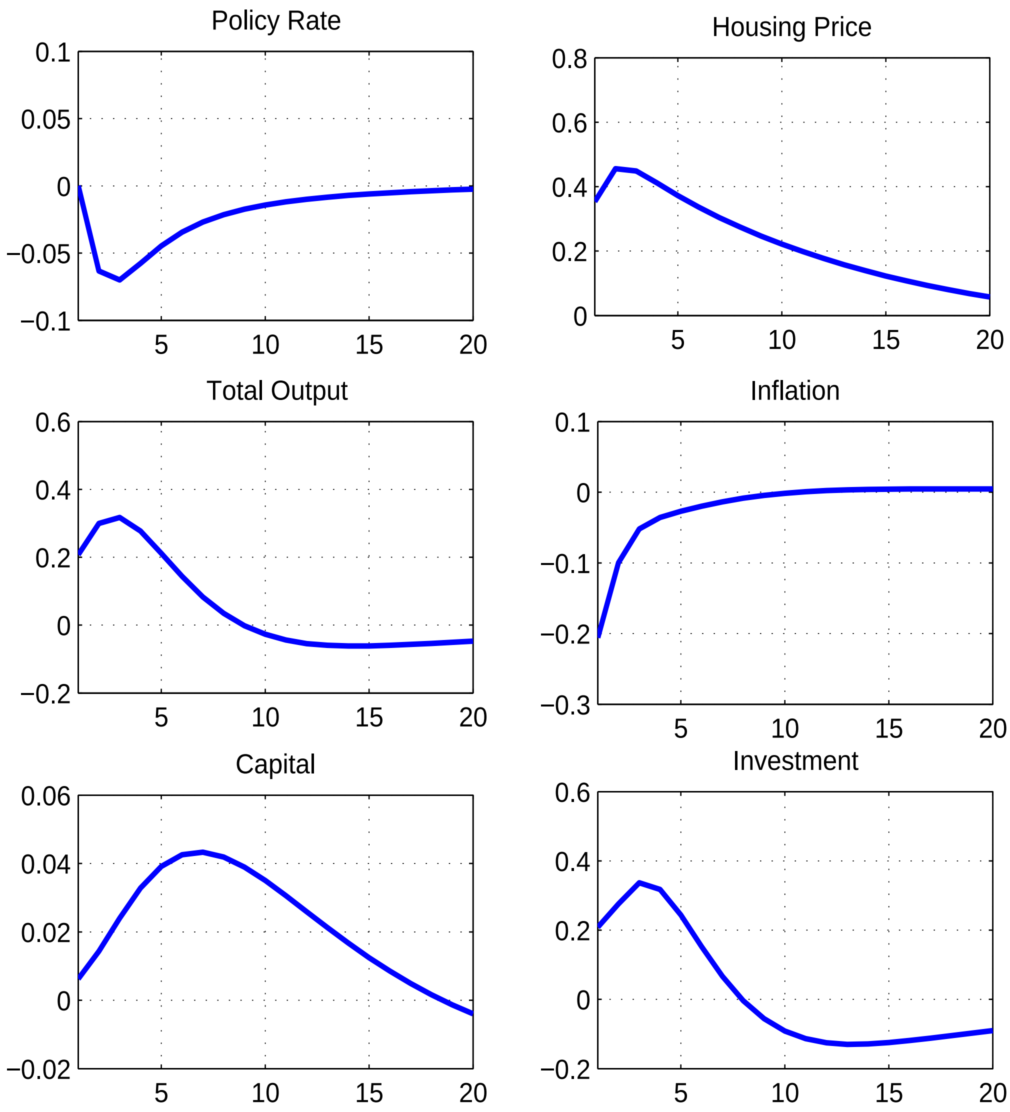
$$\hat{R}_t = (1-\rho_R)\left(r_\pi \hat{\pi}_{t-1} + r_Y \hat{Y}_{t-1}\right) + \rho_R \hat{R}_{t-1} + \hat{u}_{R,t}. \tag{L20}$$

## 8. Bankers: LTV Decision Rule

$$\hat{m}_t = \rho_m \hat{m}_{t-1} - \phi_R \hat{R}_{t-1} + \phi_q \hat{q}_{t-1} + \hat{u}_{m,t} \tag{L21}$$

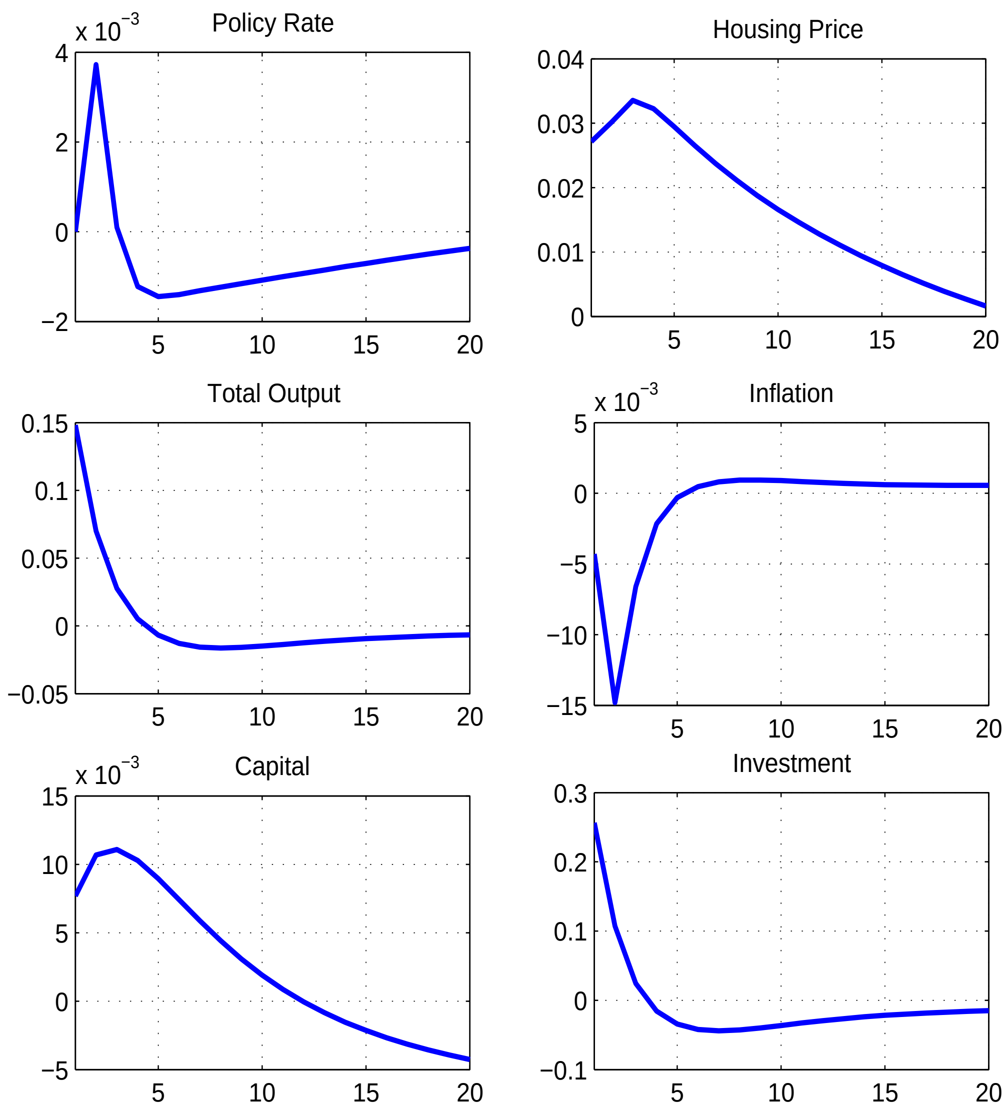
## C-3. Impulse Responses to Technology, LTV and Housing Preference Shocks

**Figure A. Impulse Responses to Technology Shock**



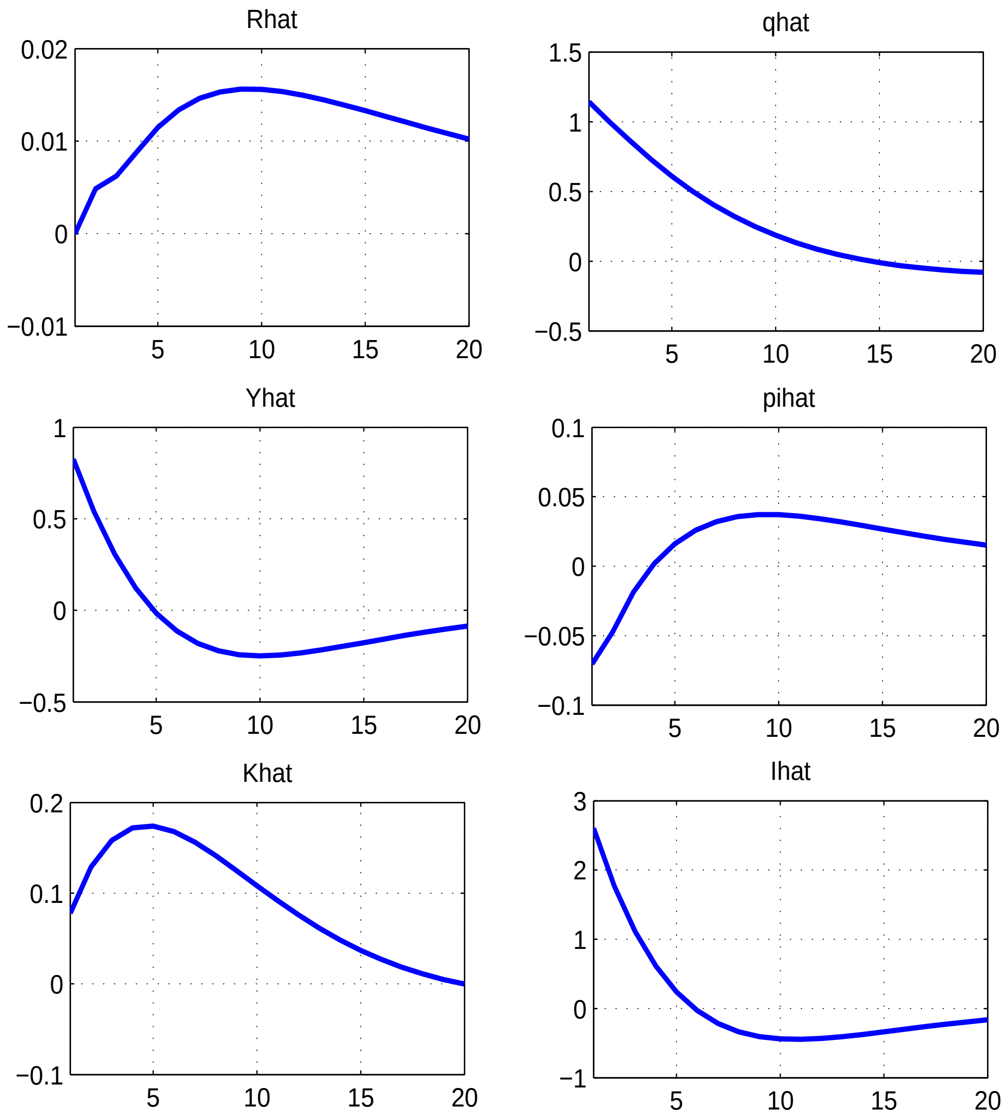

Note: The $y$-axis measures percent deviation from the steady state.

**Figure B. Impulse Responses to Positive LTV Shock**




Note: The $y$-axis measures percent deviation from the steady state.

**Figure C. Impulse Responses to Positive Housing Preference Shock**




Note: The $y$-axis measures percent deviation from the steady state.

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